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OVERVIEW REPORT

Deep Lake Water Cooling

A district cooling concept for
downtown Toronto based on
cold water drawn from the depths
of Lake Ontario

Background Papers to a Conference and
Public Discussion

Prepared for the
Deep Lake Water Cooling Investigation Group

Managed by the
Canadian Urban Institute

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Deep Lake Water Cooling

Background Papers to a Conference and Public Discussion

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CANADIAN URBAN INSTITUTE

DEEP LAKE WATER COOLING

OVERVIEW REPORT

Prepared for the Conference at Toronto City Hall and the Sheraton Centre on June 16 and 17, 1991

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This overview is designed to give the flavour of the eleven research reports commissioned for the conference; it is not a comprehensive summary of the reports. The overview is based mostly on the first four items in the list of the eleven reports on Page 8. A limited number of copies of the bound compendium of the drafts of the eleven reports, which include several hundred pages of technical material, will be available for purchase at the conference at $25 each. Copies may also be purchased in person at Toronto City Hall during the week of June 10. ***Call Beverly Kowbel at 392-9170 for details.*** The eleven reports, and some others, will be published by the Canadian Urban Institute as an appendix to the conference proceedings, after possible revision.

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A. What is Deep Lake Water Cooling?

Deep Lake Water Cooling (DLWC) is a method of cooling buildings in and near downtown Toronto, first proposed by **Engineering Interface Ltd.** in 1981.

DLWC involves exploiting the natural presence of a very large volume of cold water deep in Lake Ontario. The concept includes construction of a long intake tunnel beneath the lake bed to a pumping station on shore. Buildings in the area bounded by Queen's Quay, Bloor Street, Jarvis Street, and Spadina Avenue would be served by a grid of tunnels and branch lines. The pumping station would distribute the cold water to heat exchangers within each building. The warmer water would be returned to the lake via an outfall or outfalls located in the Inner Harbour, the Don River or elsewhere.

This method of providing naturally cold water to downtown buildings would eliminate or decrease the need for the current system of individual, electrically-driven chillers that use coolants containing chlorofluorocarbons (CFCs).

B. Why is DLWC worth considering?

Office cooling requirements are a result of heat gain from office and other equipment, sunlight through windows, outside air, and occupants. Although advances in equipment design may decrease the heat emitted, the increasing use of electronic equipment will likely offset the reduction. Hence, without changes in behaviour or expectations, the demand for cooling in downtown Toronto buildings is likely to increase.

There are three kinds of alternative to DLWC:

- One is to do nothing, but this is becoming increasing unsupportable as concerns rise about the emissions from the fossil-fuel combustion used to generate some of the electricity that drives the present chillers, and about the use of CFCs in the chillers.
- The second kind of alternative involves reducing the amount of cooling that is needed either by reducing expectations about the living and working environment or by reducing heat gain within buildings, or by doing both.
- The third kind of alternative involves cooling with other, more benign methods. These might include generating electricity for cooling with fuels other than coal, notably natural gas and even solar energy and wind, using other coolants, and operating absorption chillers that use hot water or steam rather than electricity.

The second and third kinds of alternative are both desirable whether or not DLWC is employed.

Should DLWC be implemented, it could produce these benefits and possible benefits:

- **Lower cost of cooling buildings**
- **Decreased electrical demand**: avoids the cost of new facilities required to handle the summer peak load in downtown Toronto
- **Source of potable water**
- **Reduction in pollution:** decreased reliance on coal-fired and other electrical generating stations, decreased use of CFCs, and decreased use of heavily treated water in cooling towers
- **Local labour:** creation of 10,000 person-years of local labour
- **Source of sanitary landfill:** the tunnel excavate
- **Development of Canadian export technology**
- **Ice melting on Toronto Island ferry routes:** using the warmer water returned to the lake
- **Reduction of fossil fuel imports into Ontario**.

There are also many concerns:

- **Zebra mussels** and other life forms might invade and clog the DLWC system or reduce the efficiency of the heat exchangers
- **Funds might be diverted** from conservation activity
- **Downtown traffic might be disrupted** by installation and maintenance of the DLWC system
- **Toronto Hydro's rates might have to be increased** on account of reduced sales of electricity for cooling buildings
- **The reserve of 4°C water in the lake might become exhausted.**

The major concerns, however, are not those listed above but concerns about the impact of DLWC on the environment - air, land, and water. Many of these are touched on later in this overview.

C. Status of DLWC

Engineering Interface Ltd. (EIL) has developed a preliminary design for each of the components of the project. They include: intake, intake tunnel, pump house, north-south supply and return tunnels, valve chambers, branch lines, heat exchangers, customer connections, instrumentation, and outfall.

According to EIL's concept, 4°C water from 80 metres below the lake surface will be drawn through a tunnel to a pump house on the waterfront. The tunnel will be 4.3 metres in diameter, 6.0 kilometres long and 15 metres below the lake bed. Supply and return tunnels, 2.1 to 3.0 metres in diameter, will run through the rock below Yonge Street and University Avenue. Branch lines will be microtunnelled beneath 18 east-west main streets between Spadina Avenue and Jarvis Street.

Naturally cold water will be pumped to buildings connected to the branch lines. The chillers in the buildings will be replaced with heat exchangers that will cool the circulation systems in the buildings. The replacement is expensive. However, the heat exchangers will occupy much less space than the chillers and will require less maintenance.

The system has been designed for a maximum flow of 38 metres per second. This will satisfy the anticipated demand of 300,000 tons of cooling* expected in 2015. In 1991, 200,000 tons of cooling will be required to cool the buildings in the area.

A survey in the King-Wellington area has established that there is a high degree of acceptability of DLWC to potential customers. The cost of customer connection is one of the more difficult expenses to estimate; thus a large safety factory has been incorporated in all cost estimates.

A monthly billing system has been proposed based on the amount and temperature of the water used. EIL suggests that further rate structures be examined.

About 30% of the energy input will be recovered as the water returns to the pumping station site – by means of four turbines driving electric generators.

The outfall will be designed to accept a discharge of 38 cubic metres per second with a harbour entry velocity of 150 millimetres per second. The temperature of the outfall water will be between 10°C and 12.5°C. The discharge system would involve a concrete box culvert. EIL has proposed that the warmer water be discharged into the Inner Harbour. Suggested alternatives include routing a portion of the flow into the Don River.

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*"Ton of cooling" is an engineering term for a rate of cooling that requires close to 1 kilowatt of electricity to produce.

D. Environmental Issues

Each of the environmental analyses that has been conducted includes the qualification that it is preliminary; much more extensive studies will be required should the proposal receive further support. Most environmental concerns have been directed toward the potential effects of DLWC on the ecosystem of Lake Ontario. This section describes parts of two of the studies conducted for the conference, by **MacViro Consultants Ltd.** and by **Pollution Probe**.

MacViro addressed five areas of potential environmental concern:

- **Deep Lake Water Intake.** Considerations include the depletion of 4°C water and the possibility of fish entrapment or entrainment. These concerns are considered to be unfounded or possible to mitigate through design measures. Additional investigations on deep water benthic biota (lake bottom plants and animals) are recommended.

- **Cooling Water Discharge.** Three outfall scenarios were appraised, all involving the Inner Harbour. Using computer modelling, MacViro determined that the scheme causing the least impact on Inner Harbour temperature and water quality would have two discharge points into the Harbour (at Jarvis Street and Spadina Avenue) with a portion of the outfall (10 cubic metres per second) diverted to the Don River at Bloor Street. The impact of temperature changes on aquatic life requires further investigation. The oxygen content of the outfall water would need to be enhanced. If flow is diverted to the Don River, water levels will need to be monitored and flooding prevented by a control gate during high water levels. Erosion, sedimentation, and re-suspension of deposits are either not a concern, according to MacViro, or may be suppressed at the outfall sites. Effects on ice cover are considered negligible or positive.

- **Displacement of Emissions.** Two potential environmental benefits of the DLWC proposal are: (1) the reduction of emissions associated with the generation of electricity; and (2) a decreased reliance on the CFCs used as refrigerants in chillers. Ontario Hydro's peak energy demand periods coincide with cooling load maximums. Generating plants such as Lakeview that rely on fossil fuels are used by Ontario Hydro as peaking plants. (Ontario Hydro has cautioned that a direct link between fossil-fuel use and peak-demand periods is not possible, and that by the time DLWC would be implemented coal-fired facilities may no longer be in use.) The reduction in carbon dioxide emissions resulting from a DLWC system is estimated at 146,000 tonnes per year. (The total CO_2 emission from coal-fired generating plants in Ontario is 28 million tonnes per year.) Methane and nitrous oxide are more potent greenhouse gases; emissions of them would also be reduced. Use of CFCs, which contribute both to stratospheric ozone destruction and to the enhanced greenhouse effect, could be virtually eliminated in the area served by DLWC.

- **Air Quality.** Both high air temperatures and high humidities contribute to the trapping of contaminants close to the ground – a process known technically as *fumigation*. Currently, heat is transferred from downtown buildings to the atmosphere in moisture. With DLWC, there is potential for a decrease in ambient air temperature and a decrease in humidity. This could result in a small reduction in frequency and duration of periods of fumigation.

- **Disposal of Excavated Materials.** It is unlikely that the chemistry of the shale and soil resulting from tunnelling processes will be of concern. Cost effectiveness may argue for the use of this material as fill.

Other factors surveyed in less depth by MacViro were the issues of heat rejection into Lake Ontario, heat rejection into the atmosphere, and water surge possibilities. Negative impacts due to heat rejection into the lake or the atmosphere are not anticipated. Water surge is a common problem in potable water systems and may be avoided with proper design.

Pollution Probe conducted a preliminary examination of the potential ecological impacts on nearshore ecosystems, with some attention to the possible effect of locating the outfall offshore. The Pollution Probe researchers recommend that neither the Inner Harbour nor the Don River be considered as an outfall location. Changes in flow volume and temperature, increased erosion, increased sedimentation, and resuspension of contaminated sediment may cause negative impacts on plant and fish species. Offshore outfall is considered the least environmentally disturbing option; but it requires much further study.

The report by Pollution Probe notes that the flushing effect of an increased volume of water flowing through the harbour or the river could improve the quality of the water, but pollutants would be moved into the open lake. Currents outside the inner harbour flow to the west; as a result, contamination of the western beaches or spawning grounds in the open lake could result. Dilution by the outfall water of the contaminant loadings in the Inner Harbour or the Don River could result in a false sense of security about quality of Lake Ontario water.

Adverse ecological impacts could also be caused by the proposed intake system. Fish entrapment in the tunnel, entrainment of plankton and larvae, and impingement of fish against the intake screen are possible effects that need to be prevented.

Suggestions to flush the sewer system with the used cooling water, to create decorative waterfalls in the downtown core, and to recharge aquifers were all rejected.

Pollution Probe also cautions about *ecosystem surprises*: changes to a local ecosystem may result in unanticipated impacts on the larger ecosystem, namely the Great Lakes.

Further concerns raised by Pollution Probe include:

- The importance of adequately addressing energy efficiency prior to implementing DLWC, possibly through full-cost pricing of electricity.
- The prospect of expansion of DLWC here and to other places, and a consequent cumulative detrimental effect on the Great Lakes ecosystem.
- The need to avoid chemical treatment of the DLWC water.

E. Financing and Managing DLWC

The length of the environmental approval process will be the determining factor in construction scheduling and therefore cost. The proposed schedule allows three years for environmental assessment. However, cost estimates are based on a pessimistic schedule that involves a 1997-1998 construction start.

The estimate of total cost of the construction of DLWC includes provision for, among other items, consulting fees, construction, contingency, heat exchangers, customer connection, customer engineering, taxes and interim financing. Some of these items may be borne by either the customer or the proponent.

Before accounting for a subsidy by Ontario Hydro, the cost of DLWC is estimated at $611,000,000. The net cost after incorporating the Ontario Hydro thermal storage incentive of $400 per kilowatt is $475,751,800.

The first issues to resolve involving the economics of DLWC are whether it can be financially self-sustaining and whether it should be. If environmental or economic considerations point to a subsidy, two methods are suggested by the **Canadian Institute for Environmental Law and Policy** (CIELAP). Both are consistent with the polluter pays principle. One is to levy all actual and potential customers. The other is charge all the customers of Toronto Hydro or Ontario Hydro - on the grounds that DLWC will reduce pollution from electricity generation.

The question of ownership and management of DLWC was also addressed by the CIELAP. Options include:

- A municipal corporation
- Toronto Hydro
- A specially established provincial crown corporation
- Ontario Hydro
- A business corporation.

In each case, the proponent will be accepting the risk of a deficit, as well as the potential benefits. The manner of ownership will determine the extent of taxes paid to various levels of government.

Other issues related to proponency include the costs of borrowing, which would be high but less expensive for a provincial agency. Consequently, 'profit' potential is higher for a provincial crown corporation than for a municipal corporation. There may be public resistance to an already large and powerful corporation such as Ontario Hydro becoming larger and more powerful. A private venture may be most susceptible to demands for expansion of the system should DLWC be a success. Expansion may not be in the public interest if other options could meet the demand for cooling at a lower environmental cost. A business corporation may be the most adept at exercising discipline with respect to control of costs.

Tenants and building owners would prefer an ownership scheme that would minimize their costs. However, it is not possible to draw clear relationships between DLWC rates and the ownership options.

F. What next?

After the public conference on June 16 and 17, discussion groups will meet on June 18 to address these questions:

- Is there enough supportive evidence and interest to suggest that consideration of DLWC should continue?
- What issues and alternatives should be considered during an approval process for DLWC under the Environmental Assessment Act and other legislation?
- Who should own and operate the system?

A report on the conference and discussions will be issued by the Canadian Urban Institute on June 19. If the answer to the first question above is "yes" the DLWC Investigation Group* will reconvene at 7.30 a.m. on July 27 to review a report by the Canadian Urban Institute as to how consideration of DLWC might proceed.

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*The DLWC Investigation Group, which is funding the conference and associated activities, comprises representatives of the City of Toronto, Metropolitan Toronto, Ontario Ministry of Housing, Ontario Ministry of Energy, Ontario Hydro, Energy Mines and Resources Canada, and the Toronto District Heating Corporation. Neither the eleven research reports nor this summary necessarily reflect the views of the DLWC Investigation Group or the agencies represented by its members.

G. List of reports produced for the Conference

Engineering Interface, *Position Paper for a Lakewater Cooling System for Downtown Toronto*

MacViro Consultants, *Environmental Studies Report for the Deep Lake Water Cooling Investigation Group*

Pollution Probe, *An Examination of the Ecological Impacts of the Deep Lake Water Cooling System on Nearshore Ecosystems*

Canadian Institute for Environmental Law and Policy, *Deep Lake Water Cooling: Cost Recovery and Ownership Issues*

Energy Probe, *Is Deep Lake Water Cooling a "Megaproject"?*

Member, DLWC Investigation Group, *Deep Lake Water Cooling – Financial and Organizational Considerations*

Allen Associates, *Deep Lake Water Cooling Alternatives*

Metropolitan Toronto Works Department, *Deep Lake Water Cooling as a Supplemental Municipal Water Supply*

City of Toronto Department of Public Works and the Environment, *Deep Lake Water Cooling: Construction Impact on Downtown Traffic*

City of Toronto Department of Public Works and the Environment, *Central Air Conditioning – Noise Ramifications*

City of Toronto Department of Public Health, *Environmental and Health Impacts Associated with Cooling Towers*

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POSITION PAPER

FOR

A LAKEWATER COOLING SYSTEM

FOR

DOWNTOWN TORONTO

May 28, 1991

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ACKNOWLEDGEMENTS

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Current activity in the review of lakewater cooling is a result of the long term interest shown by Councillor Richard Gilbert of Metro Toronto and Toronto District Heating Corporation General Manager, Kevin Knox.

Further appreciation is extended for the leadership offered by Councillor Jack Layton of the City of Toronto and Aubrey Leblanc of the Ontario Ministry of Housing in forming a Steering Committee to investigate the potential for lakewater cooling.

Other members of the Steering Committee who have supported this review, financially, include Gerry McIntyre, P.Eng., of Ontario Hydro, Carman Chisamore of the Ontario Ministry of Energy and Michael Wiggin, P.Eng., of the Department of Energy Mines and Resources.

Special mention must be made of Dr. Farrell Boyce of the Department of Inland Waters who volunteered his knowledge of lake temperatures and various companies and individuals who were retained for special advice. These include the firm of Proctor & Redfern Ltd. for costing and design of the pump house, intake tunnels and outfall, Dr. Gerald Mackie for comment on zebra mussels, Dr. Douglas Baines for calculation on the rise in temperature of the water moving through the system and Sayers Associates Ltd. Mechanical Contractors for branch line costing.

Another tribute is owed to Miss Deborah Field, Executive Assistant to Dale Martin, City of Toronto Councillor, for suggesting the concept of a charrette during the first meeting of the Investigation Group.

R.T. Tamblyn
Chairman, Engineering Interface Limited

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LAKEWATER COOLING - AN EXECUTIVE SUMMARY

1. What is it?

It is a concept for cooling the buildings in an area bounded by Bloor, Jarvis, Spadina and Queens Quay streets.

It would draw upon a permanent and self-replenishing source of 4°C water from an 80 m depth in Lake Ontario. This water would displace existing water chilling systems. By the year 2015, if not replaced by lakewater, these system would total 300,000 tons of cooling capacity and require up to 300 MW of electricity.

2. Why wasn't it done before?

The cost of the 6 km long intake tunnel and 8 km distribution tunnels is significant. Just as the subway system had to wait until the 1950's for ridership, the lakewater system has had to wait until the 90's for usership.

Lakewater was used for cooling in downtown stores in the 1940's. The problems with this were that the systems soon used up the capacity of the water mains and also that the water rose to 15°C in August and September - a temperature too high for adequate cooling. The City water intakes are too shallow to prevent this temperature rise during the time that onshore winds drive surface water to the north shore of the lake.

3. What are the Elements of the System?

From the start of its traverse, the lakewater will enter an intake 6 km offshore. It will then travel through a 4.3 m diameter concrete lined tunnel to a pump house located at the Toronto waterfront.

Pumps will deliver the water to supply tunnels running through the sandstone rock below Yonge St. and University Ave.

The water will then be carried into branch lines which will be microtunnelled under 18 main streets in an east-west direction. These will be valved in such a way that one supply tunnel can be shut down for service or new connections.

The buildings will be connected to the branch line "drive chambers" with smaller pipes driven through the ground under other services which lie in the street allowances. In some cases these supply and return lines will feed more than one building with piping running along basement walls.

A route was surveyed for the King Wellington branch lines to ensure that there was a place for the lines and that customers would accept the concept.

The supply and return lines will connect to new basement mounted, stainless steel, heat exchangers. These, in turn, will be connected to the customer's chilled water distribution systems.

Water will return to the pump house through a parallel set of pipes and tunnels. It will then run through recovery turbines which will recapture 29% of the power needed to drive the pumps.

The net power requirement for the pumps will peak at 23 MW. The net avoidance of electric demand by the year 2015 will be 300 MW - 23 MW or 277 MW, a saving of 92.3%.

The lakewater pumps will use less power per ton hour of cooling delivered. This differs from the on site chillers which use more. The reduction in annual kilowatt hours needed for cooling will be 96.5%.

4. What are the Advantages?

i) Avoidance of electric demand and postponement of new generation cost.

ii) Postponement of new transformer and switchgear investment in downtown Toronto.

iii) Reduction in overall cooling cost for a 40 year period of over 85%.

iv) Elimination of over 1,000,000 lbs. of CFC refrigerants used in 700 chillers in downtown Toronto.

v) Provision of an intake deep enough to be mussel free (probably) for Metro Toronto potable water supply.

vi) Financial relief to building owners who are faced with the cost of converting chillers to use HCFC in this decade and again to HFC refrigerants before the year 2020.

vii) Reduction in CO_2 and NO_x emissions at the fuel fired generating plants which supply most of the energy to existing chillers.

viii) Relief of import of fuel commensurate with the energy saved.

ix) Substitution of 10,000 man years of Toronto labour for the American labour required to build the new chillers.

x) Development of an unique Canadian technology export.

xi) Regular flushing of Toronto Harbour (six times a year).

xii) Possible melting of ice on Island ferry routes.

5. What are the Concerns?

i) The time required to examine all the environmental factors involved in the scheme.

ii) Time to provide antidotes for objections which may be raised.

iii) Time to seek a large measure of customer and public approval.

iv) Time to decide how to designate the best proponent and to raise the funds.

v) Reduction of electricity sale for Toronto Hydro which will force it to raise its rates.

vi) Disruption to downtown vehicular traffic to provide the 36 valve chambers, plus drill pits for the microtunnelling at 200 metre intervals.

vii) Fear of depletion of the 4°C reserve in the lake with eventual exhaustion of the supply.

viii) Fear of warming of the lake with environmental consequences.

ix) Fish catchment.

x) Disposal of $250{,}000m^3$ of clean fill taken from the tunnels.

6. What would it Cost?

1.	Engineering:	
	Construction	$ 24,000,000
	Environment	3,000,000
	Customer	10,000,000
2.	Construction	240,000,000
3.	Construction contingency	24,000,000
4.	Heat Exchangers	34,000,000
5.	Customer Connections	107,000,000
6.	Taxes	71,000,000
7.	Interim finance	98,000,000
	Sub Total	$611,000,000
Assumed Ontario Hydro Incentive		142,000,000
	Net Cost	$468,000,000

7. Would it pay for itself?

The cost of several scenarios was examined over a 40 year span with the following results:

	40 YEAR COST	PRESENT WORTH
ON SITE CHILLERS		
• 1300 Equiv Full Load hrs/yr	14,680,000,000	1,696,876,000
• 1000 Equiv Full Load hrs/yr	13,794,000,000	1,596,639,000
LAKEWATER COOLING		
• BASE CASE		
- 1300 Equiv FLH/yr	2,533,000,000	471,027,000
- 1000 " " "	2,500,000,000	470,000,000
• Slow OME Approval - 6 yrs	2,882,000,000	631,355,000
• Fast OME Approval - 2 yrs	2,392,000,000	449,394,000
• Slow Customer Connection	2,437,000,000	421,226,000
• 100% Cost overrun	5,093,000,000	1,050,000,000
• No Hydro Incentive	3,152,000,000	619,700,000

If the lakewater cost was allowed to escalate at 5% commensurate with electric cost, it would develop a fund for environmental works of 6 1/2 Billion dollars over 40 years. This would still leave a 5 1/2 Billion saving for customers.

In all cases, the cost of energy and serviced was allowed to escalate at 5%/year and the cooling requirement was presumed to grow from 200,000 tons in 1991 to 300,000 tons in 2015 at a rate of 1.7%/yr.

A sensitivity analysis of the cost per ton hour for some of the significant variables is shown on the graph below:

8. How long would it take?

The schedule depends upon the time taken to receive Ontario Ministry of the Environment approval.

Preliminary engineering would take a year. OME approval may take from 2 to 6 years.

Construction and commissioning could be complete within three years of final OME approval.

The cost has been examined on the basis of 2 yr, 3 yr and 6 yr OME approval time.

If arrangements to proceed could be completed by 1 January 1992, the lakewater system could operate as early as July 1997 or as late as January 2002 depending on approval time.

BACKGROUND AND REASON FOR POSITION PAPER

1981 Report

Engineering Interface Ltd. was retained for the original report by Peter Favot, Manager of Research for Canada Mortgage and Housing Corporation.

The finding of that study was that lakewater cooling was feasible. The report showed that lakewater selling at 5¢/ton hour, or half the cost of operating on site chillers, would provide a 20% return on investment for the proponent.

The project was given the acronym FREECOOL to identify it with lack of charge for the cooling medium.

A video was developed to dramatize the report. This was shown to the City of Toronto and several other potential operators but no action ensured.

1984 Report

In 1984 the Ontario Ministry of Energy, in cooperation with the Department of Energy Mines and Resources, recommissioned Engineering Interface Ltd. to update the report and seek a developer.

The new report found that costs had increased by 10% but that the ROI could still be attractive if the selling price of lakewater was raised by a like amount.

Major oil companies were approached along with Noranda and Consumers Gas. None felt that the return on investment justified the risk and none was prepared to finance further investigation.

1991 Report

The increase in chilled water usership in downtown Toronto combined with several other factors led Councillor Gilbert and others to seek a re-examination of the lakewater cooling concept. The new review has led to this "position paper" and a charrette to allow wider participation in the study.

The new factors which justify this paper include the need by Ontario Hydro to avoid increase in electric demand, the need by the City of Toronto to avoid the use of CFC refrigerants and, ultimately, HCFC refrigerants, the expense for building owners in modifying or replacing chillers to suit new refrigerants and the need of Metro Toronto to have a potable water intake deep enough to minimize the zebra mussel problem.

OUTLINE OF THE CONCEPT

The lakewater cooling system consists of a deep water intake, intake tunnel, pump house, supply water tunnels, valve chambers, branch lines, heat exchangers and connections to customer's chilled water distribution systems. The zone to be served is a 10 km^2 area presently bounded by Bloor Street, Spadina Ave., Jarvis Street and Queen's Quay. The zone boundaries have been set with respect to the density of cooling load and the static head pumping penalty of delivering water north of Bloor St.

It is assumed that the lakewater system will be designed for a connection to 300,000 tons of water cooling by the year 2015. This compares with a measured load of 200,000 tons in 1991.

Intake

The intake is located approximately 6 km from the Toronto waterfront in order to be within the region where the water remains at 4°C at lake bottom. See Figure 1.

Information on Lake Ontario water temperature has been furnished by the Department of Inland Waters. This is based on a joint USA-Canada survey of lake cross sections taken in the late 70's and on monitoring of lakewater conditions at various depths on a monthly basis since that time. Figure 2 depicts the lakewater temperature based on depth and time of year for the cross section containing the proposed intake. The slight rise to 5°C shown at 80 m depth in October is of little concern since building systems are not in need of their coldest water at that time. 4°C water is found at the lake bottom, permanently, since this is the temperature at which water is most dense. As long as the winter ambient temperature drops below 4°C at the lake surface, 4°C water will form and descend to reinforce the volume residing below. The lowest volume of 4°C water in the lake will occur in late September. This volume is estimated by Dr. Farrell Boyce of Inland Waters to be 185 x 10^9 m^3. The annual draw by the lakewater system is estimated to be 178 million m^3 when the system reaches full capacity by 2015 A.D. The draw down of 4°C water by "Freecool" is expected to be less than 15 mm or 1/10 of 1% of the volume available. This is a small amount by comparison with seasonal variations according to Dr. Boyce, whose letter on this subject may be found in Appendix A.

Concern has been expressed that the "greenhouse effect" will terminate the generation of 4°C water at the lake surface and thus defeat the concept. At present, some 3955 hrs/yr. exist below 4°C in the Toronto area. See Figure 3. Even if the average temperature rises 5°C in the next 50 years to the St. Louis temperature, as predicted by some scientists, it is apparent from Figure 3 that there will still be 2260 hrs/yr. of weather below 4°C - enough to replenish the supply. In any case, an extension of the intake to the 100m depth would in itself provide some 50 further years of supply.

For the intake to function successfully, it must draw water horizontally. A vertical draw down would bring in warmer water but, since the warmer water is lighter, energy must be exerted to make this happen. Dr. Douglas Baines, of the Mechanical Engineering Department of the University of Toronto, estimates that intake velocities below 0.3 m/sec. generate insufficient energy to capture the warmer water. Therefore the intake is sized to handle its maximum flow at 0.15 m/sec. in order to be conservative.

The intake may be designed for either horizontal or vertical withdrawal with dimensions as shown in Figure 4. The vertical withdrawal scheme may be a bit smaller and less expensive but the budget estimate allows for either, as may be decided by future study.

There is concern for fish capture, although the number of fish present at this depth is small compared with the shallower intake depths used for intake by Ontario Hydro and the City of Toronto. It is worth noting that the intake with the vertical withdrawal will capture fewer fish.

Dr. Casselman of the Department of Fisheries, contacted in a phone conversation, noted the presence of smelt and some scrod at the 80 m depth. Lake trout are also known to swim occasionally to this depth in pursuit of the smelt. Some fish are liable to be captured at the intake although the low intake and tunnel velocity allows them escape if they choose to swim against the flow. Fish which continue toward the pump house will be trapped on the rotating screens and backwashed into the harbour.

The intake will be screened with apertures small enough to arrest large objects but small enough to avoid blockage from detritus.

The intake will be assembled on barges and lowered into position when the intake tunnel and tunnel entrance are completed. Divers, using helium air support will make final adjustments to complete the installation.

Intake Tunnel

The intake and intake tunnel are sized for the maximum flow of $38m^3$/sec. anticipated in the year 2015. The tunnel will be of 4.27 m finished inside diameter. The size is determined by a 7 m draw down pumping limit at the pump house. It will be lined with 300 mm of reinforced concrete. It will be augured through native sandstone rock below the lake bed. The tunnel will slope downward slightly toward the pump house as shown on Figure 5. This allows any water leakage to flow away from the drilling face to protect the workers. It also allows the railroad cars which carry away the excavate to run down hill in their loaded condition, reducing energy and air pollution in the tunnel. The downward slope of the tunnel does, however, entail a 100 m deep well below the pump house. This adds some expense and construction time to the project.

Studies were conducted to examine the prospect of excavating the intake pipe from the surface to beyond Toronto Island and, then, laying the intake pipe on the lake bed. This was abandoned because of the disruption for islanders and boaters caused by excavation in the harbour, across island wet lands and offshore. It was also felt to add to concerns that the water would not reach the pump house at its original 4°C temperature. Dr. Baines estimated that, within 24 hours of initial flow, the rock around the drilled intake would be cooled to 4°C for a distance of one metre. Temperature rise, thereafter, in the intake would be too small to measure. With a lake bed intake, however, the intake walls would be subjected to warmer water in the summer, so that intake temperature at the pump house would be less well assured.

The route of the intake tunnel was studied based on several pump house locations. One location, suggested by the Toronto Harbour Commission on their land adjacent to the Eastern Gap, was abandoned when it was found that there were at least two locations which could be considered at the Toronto waterfront. Each of these allowed for shorter tunnel excavation and make it more economic to install energy recovery turbines on the lakewater outflow. Other locations involve both private and public properties adjacent to Queens Quay. In view of the potential income to the City or the prospect of free cooling to a private land owner, no funds have been allocated to the purchase of the pump house site.

Consideration has been given to a larger intake to take care of development beyond the year 2015. In one sense there is, already, a 25% provision for expansion. The system is designed to accommodate building systems with a chilled water range averaging 7.5 l/m (2 US gpm), e.g., 6.1°C (43F) to 12.77°C (55F). In operation, however, the lakewater is expected to reach the buildings at 4.44°C (40F) so that the lakewater range can be extended to 8.33°C (15F), e.g., 4.5°C to 12.5°C approximately.

A further boost to system capacity is expected from the design of lakewater rates. The lakewater itself, is not currently charged for by the Province, but the pump energy is a significant cost. For this reason, credits will be given to customers who increase their chilled water range to return water to the system at more than 12.5°C. This will allow any given water volume to perform more cooling.

Since the tunnel is expected to serve up to 200 years, it may seem shortsighted to provide capacity only to the year 2015. An optional price of $23,000,000 was calculated to enlarge the tunnel to 5.65 m diameter in order to double its existing capacity. Future development in downtown Toronto must be related to improvement in transportation access. Lacking solutions to this, at present, it is difficult to quantify further expansion. If the system must be extended beyond 200% of current design, it would seem reasonable to start over again with new intakes and new tunnels.

A new concern for all existing Lake Ontario intakes is the onslaught of the zebra mussel. Some serendipity is involved here as the mussel is not known to survive below a depth of 55 m. A more detailed analysis of this situation is contained later in this paper.

The lakewater system, once started, must continue in use without a shut down of any kind. This raises concerns for the intake tunnel which has no spare. If an earthquake were to cause a fracture which took the tunnel out of service, it is likely that downtown buildings would be too badly damaged to require cooling. Further, the buildings might be shut down, anyway, for lack of power since Ontario Hydro intake water tunnels would also be damaged. Fortunately, the City of Toronto has been free of severe earthquakes for all recorded time.

Tunnel inspection is expected to be carried out by robots and tunnel maintenance, if ever required, can be managed with small manned submarines. This work would be carried out during periods of low flow.

Some interest has been expressed in knowing the cost of extending the intake to a greater depth as well as increasing its capacity. The following table lists 1991 cost, less fees, taxes and contingencies, for several choices.

		Intake Cost Million $	
Intake Depth Metres	Intake Length km	For 100% Base Flow (4.27 in. dia.)	For 200% of Base Flow (5.65 in dia.)
80	6	31	54
90	8	41	72
100	12	62	85
130*	20	103	156

* This is the deepest part of the lake alongside Toronto and is 5 km from the USA border.

Pump House

The pump house has been designed to handle the maximum design flow of $38 m^3$/sec. for the year 2015. It comprises three levels. A small sub basement has been arranged to accommodate the rotating filter screens. A basement of 5500 m^2 area and 14 m headroom has been arranged to contain the intake pipe, the energy recovery turbines and discharge outlet, the supply water ring main, surge vessels and miscellaneous switchgear associated with the recovery turbines. See Figures 6, 7 and 8. The main floor houses 16 pumps, each with a capacity of 3.15 m^3/sec. Four pumps are designated as spare. Several of the pumps will be equipped with variable speed motors to enable the matching of pump capacity with system demand. The pumps will be of vertical turbine design, capable of incorporating extra stages in case the pumping head should need to be altered in the future. The pumping station is described in greater detail in the report by Proctor & Redfern Ltd. included as Appendix B.

The main floor is circular with a diameter of 42 metres and a height of 13 metres. It provides access to the pump motors and starters. A crane rail will be provided for lifting pumps and motors out of the intake well for repair, if required.

The circular compartment of the pump house must rise 19 m above the lake level and 16.3 m above grade. The concrete wet well is 20 m in diameter and 29 m deep. Room can be provided for a mezzanine or gallery above the wet well so that spectators can observe the water in the wet well and instrumentation which displays flow rates and energy being saved by this unique plant.

In case of an electric power outage, the, up to, 86,000 tonnes of water flowing in the intake, at 4.27 m/sec, must have somewhere to go. Provision is made for this surge to overflow directly into the outfall chamber. Pneumatic pressure vessels are also provided in the basement to minimize surge shock in the discharge system.

As shown in Figure 5, there is a 38 m static head on the pumping system caused by the increase in elevation between the waterfront and Bloor St. Eighty percent of the pump energy required to overcome this head, less friction loss in the return tunnel may be recovered with four turbines. These are, essentially, pumps driven backward by water returning to the system outfall. The turbines are connected directly to electric generators which feed the pump house power source. The 12 supply pumps necessary to provide the ultimate 38 m^3/sec will each draw 2.6 MW for a total of 31.3 MW. Each turbine will recover 2.25 MW for a total of 9 MW, or 29% of the input energy. The net energy to drive the system will peak at 22.3 MW. This compares with the 300 MW peak assumed for the replaced chiller load.

The lakewater system benefits, however, from a declining ratio of energy per ton hour on reduced loads, while the on site chillers use more because the water tower fans and pumps are unable to follow load variations as well as the chillers. Consequently, the annual energy requirement for the ultimate system design is 16,934 MWh/yr or 3.4% of the 491,175 MWh/yr requirement of the chillers.

The pump house will be designed with architectural flair as befits a world class installation that can be a public attraction.

Although the pump house will require only 70% of its ultimate capacity, if started up in 1999, the budget costing assumes that all pumps will be installed. Initially, there will be nine of sixteen pumps required for maximum load. Later, 12 pumps will be required.

The pump house could be equipped for a 25% increase in ultimate capacity with a nominal premium cost and little change in dimensions. If the pump house is designed to accommodate a 50% increase in intake, the diameter of the wet well and pump house will need expansion.

Supply Tunnels See Figure 9

The original tunnels were designed to have a vertical partition with water supplied on one side and returned on the other. It has since been decided that twin supply and return tunnels are more economical. These are being sited for location under Yonge St. and University Ave. road allowances.

The use of two supply/return systems has merit because:

- it permits shut down of one set for possible maintenance and repair during periods of light load
- it reduces the diameter of branch lines to the extent that it is possible to route them through building basements and parking garages with little loss of useful space.

The supply tunnels are more complex and maintenance prone than the intake tunnel because:

- they are under a positive pressure of up to 6 bars (100 psi)
- there are many connections to branch lines which represent a source of water leakage
- new connections may need to be added in the future, either for branch lines or a possible booster pumping station, feeding north to St. Clair Ave.

The supply tunnels will have concrete liners which are more heavily reinforced than the intake tunnel liner. Steel inserts with water bars will be placed in the tunnel liners before the concrete is poured. Later, the steel branch line risers will be augured down from valve chambers to be welded into the steel inserts. The concrete liner will be considerably thickened at the point of connection.

The supply and return tunnels will each be 3 m (10 ft) in diameter between Queens Quay and Queen St., then reduced to 2.1 m (7 ft) in diameter from Queen St. to Bloor St.

Tenders will be called on the premium cost to enlarge the tunnels to 3.7 m (12 ft) in diameter to allow for up to 50% system expansion. A greater increase should be contemplated only with additional tunnels.

It is intended to drill the supply tunnels through sandstone rock. However, the rock elevation drops away from grade as shown in Figure 10. Later design will consider a shallower tunnel elevation, which entails more expensive drilling through rubble and glacial till. However, the extra cost may be more than offset by the longer risers necessary to connect the branch lines from the valve chambers to the deeper rock tunnels. The budget cost provides for either tunnel elevation.

Valve Chambers

Access to the branch line valves will be arranged in concrete vaults located under street intersections where shown on Figure 9.

Each branch supply will be connected to both supply water tunnels. Each branch return will be connected to both return tunnels. In this way the isolation valves permit the branch lines to be connected to either or both supply/return tunnel systems. This will permit continued operation if one set of tunnels is ever shut down for maintenance.

The valve chambers will have surface access. They will be deep enough and broad enough to permit the installation of valves and tee fittings while leaving room to mount the necessary equipment for thrusting the branch piping through to the next building or connection chamber. This forcing process is known as microtunnelling.

The work on valve chambers will cause some reduction in traffic flow during construction but represent the least troublesome way of installing and servicing the system. The exact location of the chambers will be made to suit the least disruption of existing street services.

Branch Lines

The routing of the branch lines has been studied by a special survey of the thirty eight buildings located in the heaviest cooling zone between King and Wellington St. and between John St. and Church St. The branch line was examined in two ways:

- by running the headers principally through the building basements with microtunnelling across nine rights of way as shown in plan in Figure 11 and as detailed in sections Figures 12a through 12 g
- by running the headers under King and Wellington Sts. via the microtunnelling concept and connecting the buildings from "drive and reception" pits located under the street at approximately 200 m centres. See Figure 13.

The first concept was costed by Sayers Ltd., mechanical contractors, using Schedule 40 steel pipe with 35 mm fiberglas insulation and jacket. The cost was determined to be $3,560,000. Of this, $960,000 was required for microtunnelling under the rights of way. The piping includes headers and branch lines or stubs to each building terminated with shut off valves. Building owners were generally in accord with the provision of piping access to serve other buildings but, typically, reserved the right to negotiate for protection against liability and for compensation in case of minor loss of storage or compromise on parking.

An extrapolation of the piping from the 35, 739 tons of cooling served by this branch line to the 300,000 tons ultimately required was made on the basis of the "foot inches" of pipe required for the headers on this branch to the "foot inches" required for all 18 branch line headers shown on Figure 9.

This worked out to: $$\frac{\text{3,333,000 foot inches (18 headers)}}{\text{181,400 foot inches (King \& Wellington header)}} \times \text{\$3,560,000}$$

or: $65,400,000 at 1991 prices.

The second form of piping would be installed at a 4 to 5 metre depth, as required to avoid street services. Microtunnels to the buildings would be taken directly from the "drive and reception" pits to the buildings. As shown in Figure 13, there will be a need for basement piping in some cases to feed more remote buildings. However, this piping will be smaller and less likely to consume useful volume.

Some idea of the complexity of existing street services can be gained from Figures 13a and 13b which show the location of the proposed valve pits at Yonge Street and University Avenue.

The piping under the street can be installed in any of three ways as shown in Figure 14. An estimate of the cost of each technique has been provided by James Thompson of Jason Consultants. This can be found in Appendix B. The unit costs include the drive pits and piping which is Schedule 40 steel, insulated for supply and return. All piping has external and cathodic protection against corrosion.

The costs are summarized in Figures 15 and 16 for each of the three concepts:

Method A	(twin pipes in conduit)	$70,500,000
Method B	(supply pipe within a return water conduit)	$58,000,000
Method C	(direct bury)	$43,000,000

As a result of these examinations, a figure of $70,000,000 has been carried in the initial cost estimate. Some of the building connections will not be required until new buildings are brought on line. However, the cost allows for all initial connections to be made by 1998.

Heat Exchangers

Heat exchangers play a vital role in the lakewater cooling system. They prevent physical contact between the piping systems which presently cool the buildings and the lakewater itself. This isolates the hydraulic pressures at the base of the tall buildings from the lakewater pumping system. This, in turn, avoids pumping energy to overcome the static head of tall buildings and isolates potential damaging pressures from the piping circuits of the low buildings which are designed for limit of 8 bar (125 psi). The physical separation afforded by the heat exchangers also preserves the integrity of the corrosion protection in the building circuits while protecting the lakewater piping from fouling which may be present in poorly maintained building circuits.

The drawbacks of heat exchangers are:

- high cost
- temperature increment to permit heat transfer

Koch heat exchangers quoted for Tower 1 of the Toronto-Dominion Centre, have a 1991 cost of $500,000 plus taxes or $575,000. See Appendix C. For a 6000 ton load this equates to $95.83/ton. These plate type units are 25% more expensive than standard 304 stainless steel units because they must withstand 300 psi pressure to interconnect with the main distribution piping on the 42nd floor. They are also expensive because of the need to cool the building water to within 1°C of the lakewater supply. This narrow delta T is necessary to serve systems designed for chilled water as low as 5.55°C (42F). Many systems operate satisfactorily at chilled water temperatures as high as 8.33°C (47F). The owners of these systems have the option of buying units with a delta T as high as 3.78°C (7F) and thus use heat exchangers of less than half the size and cost.

In any case the allowance for the purchase and placing of the heat exchangers has been conservatively estimated at a 1991 cost of $125/ton.

The heat exchangers will take up less room than the chillers they replace. An arrangement for Tower 1 is shown in Figure 17. It will be seen that the heat exchangers consume an area equal to only three parking spaces. The chillers occupy 10 times this area. The chillers have many moving parts and require regular maintenance. The heat exchangers have no moving parts and should require hosing down only once a year.

Customer Connections

Of the 38 buildings surveyed only four had the chillers located in the basement. It has been trade practice to place the chillers in the penthouse. Water towers are preferred at the top of the building to be able to reject the chiller waste heat without fear of air recirculation. It is less expensive, then, to run a power cable to a penthouse mounted chiller than two large condensing water lines from a basement mounted chiller.

The chore of connecting basement mounted heat exchangers to the chilled water distribution centre in the penthouse necessarily adds cost to the lakewater system.

In the King-Wellington building survey, an estimate was made of the distance from the lakewater piping stub to the chiller location. This is detailed on the Customer Information spreadsheet. Figure 18. Piping interconnections were sized with regard for the acknowledged peak cooling capacity and the chilled water range. The riser location in the case of upper floor chiller mounting was assumed to be the corners of the stairwell landings. See Figure 19. It is often hard to find any room left in pipe shafts and still harder to make use of any that is found.

The cost of pipe, insulation and insulation jacket was taken from 1991 Means Costing Sheets. This is a well respected American information source for pricing HVAC systems. The costs, equated for Canadian practice, with taxes added, are shown on Figure 20 to average about $10 Cdn. per "foot inch." A 10 inch diameter pipe would thus cost 10 x 10 or $100/foot. This value is intended for clean runs in new construction. The figure used for this report is $30/foot inch or three times the normal value. Allowances are shown on Figure 18 for a modulating valve and thermostatic control to vary the lakewater flow to suit the cooling load. See Figure 21. The sum of the allowances, less the heat exchanger, was found to be $190/ton for the buildings measured. A figure of $400/ton was used in the estimate. This will provide a large safety factor for a cost which is most difficult to estimate.

Instrumentation

A flow meter will be installed on the lakewater side of the heat exchangers for each customer. See Figure 21. This will be connected to the pump house by low voltage wiring installed in conduit with the distribution piping. An interface will be made at the meter so that the customer may also monitor the water being used by his system.

Monthly billing will be automated based on the number of ton hours used and modified by the average chilled water range during the billing period. A prospective rate index is shown in Figure 22. No special pains have been taken to relate the schedule to plant cost but some discipline on chilled water range should be exercised to avoid the traditional problem of central systems which have run out of pump and piping capacity before using up the plant cooling capacity. In further rate studies a rate structure with a demand charge based on flow rate and an energy charge based on cooling capacity sold should also be examined. It may turn out that the simplest charge is by the cubic metre.

Outfall

The outfall considered for the base price is one with an area to accept the ultimate flow of 38 m^3/sec with a velocity of 150 mm/sec. This could be arranged with an outlet grille or grilles in the harbour wall of 40 m length and 6 m height. The grille would be served by a concrete box culvert as shown in Figure 8.

Regular cleaning may be required at the grille area if the zebra mussel infestation materializes.

Alternate outlets could be considered in the Don River or through a bypass to the storm sewers for regular flushing.

The temperature of the water at the outfall is likely to be about 12.5°C in summer and, perhaps, as low as 10°C in winter. This falls within the Ministry of the Environment guideline of being within 10°C of natural harbour temperature. See Figure 23 for Toronto Harbour water temperature.

Downtown Toronto landscaping could be enhanced with more water display. The greatest problem and cost with pools, fountains, streams and waterfalls is water treatment and maintenance. This would not seem to apply to lakewater which could be bypassed to water displays during dry weather and run off through the storm sewer system. Without constant recirculation the problems of biological control and water hardness concentration would be minimized. There is enough pressure in the return mains in the piping south of College St. to operate fountains without even the need for a pump.

Summary and Distribution of Cooling Load

A survey of buildings has been made in the Freecool area. The floor area of the buildings was defined, in part, by Royal LePage's survey of downtown Toronto office space, by the City of Toronto's publication, "Development Projects in the Central Core, July 1990" and by casual analysis of existing buildings other than office space. The total area was found to be 16,000,000m^2 as shown in Figure 24. Office space amounts to 57%, residential to 22%, all other categories to 21%. Existing space accounts for 66% and buildings under construction 11%. The balance of 23% has come from permits applied for as detailed in the City document noted above. The growth of downtown space has been assumed at 1.7%/ year. At this rate the estimated space should suffice to the year 2015.

A firm estimate of capacity must await a detailed survey of the buildings involved. Meanwhile a rough estimate has been made using a factor of one ton of refrigeration for 100m^2 on residential and 40m^2 for other building categories. Although ignoring many buildings which are less than 2000m^2 in area, this has yielded the cooling summary of 344,000 tons shown in Figure 25. A further breakdown of cooling load for use in sizing branch lines is shown in Figure 9.

These loads may suffice to 2015 assuming all buildings with an existing chilled water distribution system will connect. About 10% of the buildings surveyed would be ineligible because their cooling systems are based on the use of air conditioning packages with no chilled water piping. Even these, however, may be connected at some time in the future after system modification.

The costing of Freecool assumes that cooling can be sold for less than the operating cost of existing equipment. With this inducement, the total load of 300,000 tons has been assumed for the year 2015.

The owners of the buildings listed on Figure 18 were visited and asked to fill out a questionnaire. A sample is shown in Appendix D.

With a maximum cooling load in excess of 35,000 tons, the King-Wellington segment will be one of the heaviest loads on the system.

Customers were also asked to indicate their willingness to allow cooling header pipes to traverse their basement en route to other buildings. The form is shown in Appendix E. No one refused to sign this form although some wished to allow room for future negotiation of liabilities.

The general attitude of the customers was one of curiosity and interest in having the service if it could be proven reliable and equal or lower in cost than their existing mechanical refrigeration.

Provision for Expansion

Factors already mentioned are the possibility of a 100% capacity increase in the tunnel. This would cost $23,000,000 in 1991, $31,000,000 at time of construction.

Increasing the supply tunnels from 2.14 m diameter, Queen St.- Bloor St. and 3.05 m diameter pump house - Queen St. to 3.66 m overall would raise tunnel capacity by up to 50% and provide for some extension north of Bloor St.

Further increase in supply will require another tunnel because of the limit in branch line capacity. The branch lines will handle some increase now but will need a future Bay St. tunnel to add 50% capacity. The pump house could have a capacity increase of up to 25% at nominal cost by substituting larger pumps in the future. An increase of 50% will require consideration initially with a budget increase of $10,000,000 in 1991 - $13,500,000 by the time of construction.

An increase of 100% overall to match the potential intake tunnel enlargement, may require a second pump house and distribution system.

Limitation in Temperature Rise of Lakewater Supply

The rock encasement of the main intake and supply tunnels will provide enough insulation that after 24 hours circulation with 4°C water, the rock will reach a temperature of 4°C within one metre of the tunnel casing. Temperature rise in the entire system has been estimated by Dr. Douglas Baines, P.Eng., to be:

	At Full Flow 38 m³/sec		At Minimum Flow (4m³/sec)	
Item	Branch Lines Buried	Branch Lines Open to Air	Branch Lines Buried	Branch Lines Open to Air
Intake Tunnel	0.07°C	0.07°C	0.05°C	0.05°C
Through Pumps	0.07°C	0.07°C	0.01°C	0.01°C
Supply Tunnels	0.075°C	0.075°C	0.05°C	0.05°C
Branch Lines	0.07°C	0.12°C	0.02°C	1.20°C
TOTAL	0.285°C	0.335°C	0.13°C	1.31°C
Final temp entering Heat Exchanger	4.285°C	4.335°C	4.13°C	5.31°C
Add Heat exchanger approach temp.	2.0°C	2.0°C	0.3°C	0.3°C
Temp. of water to Customer's system	6.285°C (43.3F)	6.335°C (43.4F)	4.43°C (40F)	5.61°C (42F)
Typical Chiller setting at Customer's plant	44F Heavy Loads	44F Heavy Loads	48F Light Loads	48F Light Loads

See Appendix I for more detail

Piping Corrosion Potential

The oxygen content of the lakewater is a concern for the steel pipe in the brranch lines. Corrosion preventive measures have been reviewed by Mr. Alan Stevens in Appendix J.

SUMMARY OF PRESUMED BENEFITS

Low Cooling Cost

This paper will show that the cost of cooling, including energy, servicing and amortization can be greatly reduced with the lakewater concept. The comparison is complicated by the fact that few owners have an accurate idea of the cost of cooling.

The most honest appraisal of this may take place when a developer decides whether to connect his new building to an existing central cooling distribution. Such decisions are made from time to time in Hartford, Connecticut and Minneapolis, Minnesota where privately owned central cooling systems serve downtown areas. In both cases the plants are selling electric or gas generated chilled water at between 25 and 35¢/ton hour US. Few potential new customers are lost at this rate.

While current rate structures for the purchase of chilled water may be persuasive, a definition of the make up of cooling cost will be helpful in dealing with potential customers.

The cost of operating on site water chillers involves both electric demand and energy charges. Electric demand is a function of occupancy and outdoor temperature. Maximum monthly Toronto temperatures at Bloor Street are shown in Figure 26. The impact of this upon the cooling load for different types of air handling systems is shown in Figure 27. Specific definition of maximum cooling load is shown in Figure 28.

It is apparent that the type of air handling system makes a significant difference to cooling requirement. About 80% of downtown systems are thought to be of the central station type with full airside economizer cooling. The cooling plants in these buildings will shut down for the winter except for those buildings which feed up to 7% of their chilled water to computer suites. The remaining 20% of buildings have compartmented air handling systems with an inadequate source of outdoor air for "free cooling". Examples of this type are First Canadian Place, Bank of Nova Scotia and BCE Place. Chillers in compartmented buildings must operate year round unless equipped for tower cooling. Those that are so equipped perform somewhere between central and basic compartmented designs.

From Figure 26 and other weather data, estimates of electric demand and energy have been made for 160,000 tons of central station cooling and 40,000 tons of compartmented systems. The results as derived in Figures 29, 30, 31 and 32 may be summarized for 1991 Toronto Hydro rates for the theoretical connection of 200,000 tons which could connect in 1991.

	MWH/Yr			1,000$ Cost of Electric Demand			1,000 $ Cost of Electric Energy		
Item	Central	Compart mented	Total	Central	Compart mented	Total	Central	Compart mented	Total
Chillers	139,200	56,300	195,500	13,251	4,390	17,641	5,498	2,222	7,720
Towers	97,000	34,900	131,900	4,768	1,608	6,376	3,832	1,383	5,215
TOTAL	236,200	91,200	327,400	18,019	5,998	24,017	9,330	3,605	12,935

Other costs for on site chillers involve service contracts, chemicals, tower make up water, the premium salary to be paid to skilled operators and the rental lost on space consumed by the chillers, condensing water pumps and towers. This is shown in Figure 32 alongside similar costs developed for lakewater cooling. A further cost which will be debated by Owners is the cost of amortizing the cooling system for its eventual replacement. Lest this be overlooked as an accounting item, the Owners must, at the least, face the probability of the cost of renewing or modifying their existing plants. The present CFC refrigerants are likely to be phased out before 2000 A.D. and their HCFC replacements before 2020 A.D.

With costs escalating at 5% per year the on site cooling cost may climb to 32¢/ton hour by 1999 when the lakewater system is ready to operate. It will be shown that lakewater cooling could substitute for about half this price.

The margin of difference can provide reduced costs for customers or a fund to improve the environment.

Electric Demand Avoidance

Lakewater cooling can supplant a 300 MW electric demand for chillers in the year 2015 with a net requirement of 23 MW for pumps.

While the 277 MW reduction in summer is no help to the Ontario Hydro winter peak, it will avoid the cost of new transformers and switchgear for Toronto Hydro's summer peaking load.

Source of Potable Water

The zebra mussel is unknown below a depth of 55 metres although active within the 20 m depth of City water intakes.

If it can be shown through ongoing studies by Dr. Mackie, et al, that the lakewater intake, at a depth of 80 m, may be free of this infestation, the tunnel could serve a secondary purpose of providing a Metro water intake. Enlargement of the tunnel diameter by one metre would provide potable water for the whole of Metro at a nominal extra cost.

Reduction of Pollution

- Electric Generation

Cooling is a "peaking" load, handled by fossil fuel fired generating stations. As such, the avoidance of 277 MW and 474,200 MWh/yr will overcome a major output of CO_2, NO_x (acid gas) and particulate matter. This is quantified in another part of the paper.

- Cooling Towers

Cooling towers in downtown Toronto will deliver up to 40 million l/s of saturated air into the atmosphere by 2015. They will also draw up to $2000m^3$/hr of water to discharge the heat rejected by the chillers. This water requires heavy treatment with biocides and anti-corrosion chemicals, some of which must be "blown down" into the sanitary sewers and some of which enters the atmosphere along with the vapour plumes.

Water towers are a source of fatal bacteria, such as legionela. They require up to 30% of the energy in the refrigeration cycle and they require regular supervision. Every building owner would be happy to see the end of their pollution, noise, vibration and upkeep cost.

Requirement for Local Labour

All chillers are manufactured outside Canada. All of the lakewater cooling equipment can be manufactured locally.

The base cost of the system in 1999, as detailed later, is $611,000,000. At $60,000/man year this will provide 10,000 man years of local labour.

Source of Sanitary Fill

The tunnel excavate should be in a "virgin" state as far as ground source pollution is concerned. Such grade A fill is now rare in Toronto. It could be used for something more profitable than an extension to the Leslie St. spit.

The 250,000 m^3 from tunnels and wet wells could be used on the ATARATIRI site which is under the potential Don River flood line. It could also be used for any of the 20 lakeshore fill requests which currently await Crombie commission approval.

Generation of a Canadian Export Technology

A successful installation in Toronto will attract attention in many parts of the world where chillers lie alongside potential sources of cold water.

Candidates include Boston, New York, Philadelphia, Vancouver, Seattle, Portland, San Francisco and Tokyo.

Canadians will have a technology lead in these areas for studies, if not installations.

Ice Melting for Island Ferry Routes

Metro Toronto is considering the purchase of an ice breaker to maintain island ferry routes.

An optional outfall for lakewater would involve pipes laid below the ferry routes.

Even in winter, the daily lakewater flow is unlikely to be less than 300,000 m^3. If fed through a perforated pipe at 10°C, or more, this volume may be enough to maintain ice free ferry channels.

Reduction of Fossil Fuel Import

Water chilling is a peaking load and, as such, will be carried principally by fossil fuel generating plants. These may be fired by coal or gas. In either case, the fuel must be imported from outside the province.

Any reduction in the use of fossil energy allowed by the lakewater cooling plant will improve the position of Ontario with respect to import tariffs and restrictions.

Source of Economic Heating

In 1981, the Freecool report noted that the building heat discarded through chilled water during winter was equal to 58% of the annual heating requirements of the same buildings. A study was made at that time showing how some of the heat exchangers provided for cooling could be diverted to heating so that heat could be resold cost effectively to the buildings through a second distribution system.

This "heating side" of Freecool has not been examined in this study. However, it is worth noting that a minimum of 20,000 tons of cooling may be expected even during winter nights. It is also reasonable to expect that chillers, capable of heat pump activity, of at least 20,000 ton capacity will become redundant. If these are assembled at the pump house and permitted to cool discard water from 12.5°C to 4°C during the 11 p.m. to 7 a.m. period, they can generate 20,000 tons x 15,400 Btu/ton x 8 hrs or 2464 Million Btu/day. At a 100 Btu/m^2 maximum heating requirement, this could heat

$$\frac{2,464,000,000}{100 \times 24 \text{ hrs/day}} = 1,000,000\text{m}^2$$

of office space. The delivery temperature from the heat pumps would be 50°C. This is adequate to heat buildings designed since 1975.

At an energy input of 1 kW/ton, or 15,400 Btu of heat production, the cost of this heating with off peak electricity is $\frac{1,000,000}{15,400}$ x \$0.0395/kWh or \$2.46/Million Btu.

If the heat was sold competitively at \$7.00/Million Btu, there would be \$4.50/MMBtu available to amortize the chiller set up and distribution. One drawback is that, with only a 10°C heating range, the piping would have to be larger than normal for hot water heating and the circuit would not integrate well with the hot water heating proposed by TDHC for its future heating expansion. However, for buildings adjacent to the pump house, the Freecool heating concept and necessary hot water storage tanks will make a lot of sense.

SUMMARY OF SPECIAL CONCERNS

Zebra Mussel

The zebra mussel has the likelihood of invading every water intake in Lake Ontario. It is a cause for concern by Metro Toronto for potable water and Ontario Hydro for generating stations.

So far, the mussel is not known to survive below a 55 m depth. Growth is impossible below 10°C and reproduction below 15°C.

A significant study is being chaired by Dr. G. Mackie of Guelph University. He was asked to contribute to this report and his statement is included as Appendix F.

Dr. Mackie is aware that the zebra mussel veliger (microscopic larvae) can propagate through the lake after birth and then settle to the bottom. It is not known whether the veliger can survive long enough in 4°C water to penetrate the lakewater system. It is also not know whether, if in the system, the veliger can grow in the 12.5°C discard stream before being flushed back into the lake.

Dr. Mackie hopes to examine the lakewater intake situation in his study and provide greater specifics to quantify any further concerns which must be addressed.

There is no doubt that mussel contamination will exist at the outfall in the harbour. For this reason it will be preferable to have the outfall in a configuration which is easy to clean mechanically.

Priority in Conservation Activity

There may be concern that funds invested in lakewater cooling could provide better returns if invested in more effective forms of conservation. There are still many opportunities for reducing fuel use in buildings but fewer in cooling.

Two thirds of the cooling load resides in office space. Here, the major cooling loads for a typical office are heat gain from electrical loads 36%, solar 25%, outside air 22% and occupants 6%. The only one of these loads with hope of improvement is lighting, although improvements in this category are being rapidly offset by greater electronic loads. Outside air is on the rise to combat air quality problems and architects are unwilling to use less glass. In residential buildings the loads are predominantly solar and ventilation. New buildings are using even more glass and ventilation is unlikely to be reduced.

In summary, the need for cooling in both existing and new buildings is likely to rise despite improvements which are expected in lighting. This would appear to leave lakewater cooling as the premier conservation solution.

Downtown Traffic Disruption

Downtown streets need no more impediment to traffic flow than the present volume of traffic.

Tunnels must lie below rights of way. Branch lines must also be laid in road allowances unless owners grant a licence to run lakewater headers through their basements. Fortunately, most owners see an advantage in this and are likely to grant permission subject to negotiation on liability. See Figure 18 for owners' opinion on use of their property.

Notwithstanding, there is need for valve chambers and access to piping from the street surface. This will be arranged as infrequently as possible with excavation and access from a side street where available. At the least, there will be 36 valve chambers to serve 18 branch lines. If microtunnelling is used for branch headers, there will be access chambers at least every 200 metres.

The excavation needed for lakewater piping will cause less disruption then the cut and cover process used in the past for steam lines, but it will nevertheless be criticized by some.

Impact on Toronto Hydro Rate Structure

The electricity sold by Toronto Hydro in 1990 was 9,550,000 MWh. The energy avoided by 200,000 tons of lakewater cooling, if initiated in 1991 would be 316,000 MWh/year or 3.3% of the total.

The impact on electric demand would be more significant since 200 MW would be deleted from a peak of 1620 MW. See Figure 33. This would have a salutary effect, however, since downtown transformer stations and switchgear are trending toward overload. Ontario Hydro estimates a $40,000,000 investment postponement if the lakewater cooling system off loads the existing electric grid.

Toronto Hydro has carried out a modelling study of the Freecool impact. The results of this may be found in Appendix K.

Depletion of 4°C Water Reserve in the Lake

A letter from Dr. Farrell Boyce of the Department of Inland Waters, Appendix A, notes that the annual withdrawal of 4°C water from the lake would depress the reserve by 15 mm.

Dr. Boyce estimates the volume of 4°C water in the lake, at its *lowest level, to be:*

$$9260 \text{ km}^2 \times (100 \text{ m} - 80 \text{ m}) \times 10^6 \text{ or } 185{,}200 \text{ million m}^3.$$

The annual lakewater withdrawal in the year 2015 will be:

$$\frac{300{,}000 \text{ tons} \times 1303 \text{ full load hours} \times 120 \text{ Gal/ton hr}}{264 \text{ Gal/m}^3} \quad \text{or } 178 \text{ Million m}^3$$

The withdrawal from the least 4°C volume will thus be:

$$\frac{178}{185{,}200} \times 100 \text{ or } \frac{1}{10} \text{ of } 1\%.$$

This is less than seasonal variations and unlikely to be measurable.

As noted earlier, the annual average temperature may be forced up 5°C in 50 years by greenhouse effects. This would convert Toronto climate to one akin to St. Louis. Even then there would still be 2200 hrs/yr of weather below 4°C with which to re-establish the 4°C reserve in the lake.

In summary, according to Dr. Boyce, the annual withdrawal might have to increase by 50 times to cause a significant difference to the volume of the hypolimnion (water below the 4°C thermocline).

Temperature Rise in the Water Supply

The on site chillers discharge 15,000 Btu/ton to the atmosphere through their cooling towers. The discharge includes 3000 Btu/ton for apparatus work heat.

The lakewater system would discharge 12,000 Btu/ton to Toronto Harbour at 12.5°C. This might be compared to about 6000 Btu/ton, at a much higher temperature, which is discharged to the lake at the Lakeview generating station.

While the Lakeview discharge will heat the water around its outfall, the Freecool discharge may actually cool the Toronto Harbour.

The maximum Freecool heat release may seem large when expressed in thermal terms, e.g., 300,000 tons x 12,000 Btu/ton or 3.6×10^9 Btu/hour. However, even this value is small when compared with natural effects. For instance, with 1000 Btu/m^2, the heat gain on the lake surface from direct sunlight, the lake will receive 1000×10^9m^2 (lake area) or 10^{12} Btu/hour. Thus, one hour of sunshine equates in heat gain to

$$\frac{10^{12}}{3.6 \times 10^9} \text{ or 277.7 hours of maximum cooling}$$

Stated another way, one hour of maximum heat rejection to the lake is equivalent to the warming effects of $\frac{3600}{277.7}$ or 13 seconds of sunshine on the lake.

Pollution of Toronto Harbour

Thermal

The maximum heat output of the lakewater system as noted before is 300,000 tons x 12,000 Btu/ton hr. or 3.6×10^9 Btu/hour.

Whether this heats or cools the harbour water depends on the natural harbour temperature. As shown on Figure 23 this remains at a 4°C temperature, November to May, but rises in summer to a stratified condition with 8°C at the bottom and 20°C at the top in summer. The average summer temperature appears to be close to the lakewater discharge temperature of 12.5°C. Hence, the cooling system is unlikely to have much effect in summer when most of the outflow takes place.

In winter the lakewater discharge may fall to 10°C. This will have a warming effect although the winter discharge volume is smaller. There should be at least enough heat however, to keep the ferry lanes clear of ice.

In any case, the lakewater outlet temperature should always fall within the Ontario Ministry of Environment guideline which limits the temperature difference between outflow and harbour to 10°C.

Biological

No chemicals will be added to the lakewater as it traverses the system. However, there may be concern that water from the 80 m depth will bring extra nutrients to Toronto Harbour. Other sections in this report will deal with this although it was noted that the phosphorous content of the water, which could encourage algae blooms, was no greater at the 80 m depth than in the Harbour according to recent measurements by the Department of Inland Waters.

It is possible that the flushing action of Freecool will help to cleanse the Harbour of pollutants which arrive there from the sewers, the Don River and boat traffic. The volume of the water in the harbour is 30,000,000 m^3. The Freecool discharge would be:

$$\frac{300{,}000 \text{ tons} \times 1303 \text{ FLH} \times 120 \text{ GPH}}{264}$$

or 178 Million m^3. There will be a pollution dilution of

$$\frac{178}{30} \text{ or 6 changes a year.}$$

Disposal of Tunnelling Fill

This has been estimated by Proctor & Redfern to be 250,000 m^3. The material will be a mixture of sandstone varying in size from sand to particles of 150 mm diameter.

It will be useful for fill if the haulage distance is reasonable.

At present, however, the base price of the system contemplates the disposal of the fill on the Leslie St. spit. This will require environmental approval and must therefore register as a concern.

Fish Capture

Fish of the smelt, scrod and alewife species are thought to be present at the 80 m depth. Although they may be few in number, there is every likelihood that they may be drawn through the intake against the rotating screens in the pump house. It is unknown whether they can survive the backwash cycle.

OUTLINE OF OPERATING COSTS

On Site Water Chilling Plants

It has been assumed for this study that money is worth 10% (long term provincial debentures can be sold at 9 3/4%) and price escalation will be 5% (inflation in Toronto is quoted at 4 1/2%, in Canada 6%). In any case, the difference of 5% between the two values is thought to be consistent and if this interval remains the same, it will be unnecessary to test the sensitivity of varying rates of interest and escalation.

The system is assumed to grow at the rate of 1.7%/year from a connected load of 200,000 tons in 1991 to a final load of 300,000 tons in the year 2015.

Energy

Three types of air handling systems are present in downtown buildings. The most common can be termed "Central System". This employs central air handling stations with arrangements for up to 100% outside air in winter to avoid having to operate the chiller. The second type of system uses air handling systems on each floor with an outside air intake shaft sized only for ventilation. These systems require chiller operation for all occupied periods unless they have been arranged to use their water tower as a "free cooling water chiller" in winter. The third type of system involves packaged air conditioners, most often on the basis of one per floor. These are usually connected to a water tower for heat rejection.

Assumptions have been made that the systems require equivalent full load hours per year of cooling as follows:

Central	1160
Compartmented	1875
Packaged	1875

Compartmented systems with tower free cooling may lie midway between central and compartmented designs. Packaged air conditioners are secondary candidates for lakewater cooling because they require new air units or, at least, the substitution of water cooling coils for their direct expansion coils.

With these assumptions in mind, central and compartmented systems were analyzed for electric demand on Figure 29 using full load hours drawn from weather data in Figures 26, 27 and 28. The energy was costed at $14.36/kW which is the 1991 Toronto general service rate including GST. The average chiller input was assumed to be 0.75 kW/ton for the compressor and 0.25 kW/ton for tower fans and pumps.

The breakdown between central and compartmented systems was estimated to be 80% and 20% respectively. The costs have been kept separate to enable analysis of this ratio.

Figure 30 defines the energy cost based on the Toronto rate of 3.95¢/kWh, including GST.

Water tower motors do not follow the cooling load as well as chillers. Some systems have only one tower fan and pump which must operate at full load for all operating periods. Figure 34 was used to establish the equivalent full load hours/year for tower motors. Figures 31 and 32 derived the electric demand and energy cost respectively.

The grand total of operating cost for 200,000 tons of connectable load in 1991 is as shown earlier on page 14.

Service

An effort was made to collect data from the 38 building King-Wellington survey on the cost of servicing chillers and water towers. On the basis of the history displayed in Figure 18, the costs were estimated at $24/ton/year for central systems and $27/ton/year for compartmented systems.

The service cost involves maintenance contracts for chillers and water treatment plus chemicals, water make up and repair. No credit was given for saving in manpower or rental of space abandoned by chillers. In reality, the servicing cost may be double the allowances used in this study.

Total

The cost of energy and service for on site plants is summarized in Figure 36.

Lakewater Pumping System

Energy

The cost of lakewater pumping to central and compartmented systems was analyzed in Figures 37 and 38. For these tables the same equivalent full load hours of cooling were used as for the on site chillers. Pumping cost was determined by analyzing the system resistance in Figure 39 and converting this to energy by assuming an 80% pump efficiency and 90% electric motor efficiency. The energy recovery turbines were assumed to capture the residual system head at a 60% efficiency. This resulted in the energy curves shown in Figure 40 and the costs shown in Figures 37 and 38. The energy curves show the favourable relationship between system capacity and energy requirement. This results from the rapid decline of piping resistance (varies as the square of capacity) when the water flow is reduced. This effect is the opposite of on site chiller systems which require higher kW/ton because of the poor capacity control on the tower motor

Electricity costs for the pumping station were taken from the Toronto Hydro 1991 Time of Day schedule since the plant draws more than 2500 kW.

Kilowatt hours were priced monthly on the basis of energy derived from the full load hours. These were calculated from the kW input for the flow averaged across the number of hours in the month.

Figures 37 and 38 were based on the ultimate capacity of 300,000 tons so that a pumping factor for the partial loads expected in each year of growth could be used in the later spreadsheet analysis. See Figure 41 for the pumping factor. The cost of lakewater cooling energy in 1991, if the system were operating, would be:

Type System	$/Yr for 300,000 tons	Capacity Factor for 200,000 tons	Net $/yr
Central	2,735,806	.465	1,272,150
Compartmented	1,434,351	.465	666,973
TOTAL	4,170,157	.465	1,939,123

This compares with the energy cost for on site chillers in 1991 of $12,935,000/yr.

Service

Administration costs were reviewed with TDHC. A sum of $250,000/yr was agreed for the 1991 cost of salaries for pump house operators. This would hire and chief and four assistants, one of whom would be in charge of automated billing.

A further sum of $200,000/yr was allowed for insurance, building energy and allowance for system repairs.

These estimates will be prorated at 5%/ year for 1999, the assumed first year of plant operation.

Total

The sum of energy and service costs, if the plant could operate in 1991, would be:

ITEM	$/YR	$/TON HR
ENERGY	1,939,123	0.0074
SERVICE	450,000	0.0017
TOTAL	2,389,123	0.0091

It is now apparent that the major cost of lakewater cooling will be amortizing the original investment.

OUTLINE OF AMORTIZATION COSTS

On Site Water Chilling Plants

Chillers become obsolete because of increase in maintenance cost, breakdowns, tube wear and the emergence of new, more efficient, models. The usual life of a chiller is 30 years. Several in the Yonge Wellington survey were found to be over 30 years. Several were already replaced within that time span.

There is a special problem today with the outlawing (by 1997) of the manufacture of the CFC refrigerant used in the existing chillers. Although the intended HCFC replacement is available, many chillers will not be able to use the new refrigerant. Others will require expensive modification. The range of cost will be from $800/ton for replacement chiller down to $250/ton for modifications. The overall cost in the Freecool area is likely to exceed $100,000,000. By the year 2014 the cycle will recommence since even HCFC is a "greenhouse gas" and likely to be phased out by 2020.

Some owners decline to consider amortization a real cost, arguing that they intend to sell the building long before they need to buy a new chiller. This begs the question of building evaluation for sale which should take into account the age of chillers. In any case, amortization should be accounted for in some way. The assumption in this report is that all the chillers are worth $800/ton and amortized over 30 years at the rate of 10% e.g., 10.6% per year. This, in turn, assumes, conservatively, that all existing chillers will last another 30 years and no one will be required to make any refrigerant changes until the new chillers are purchased.

Chillers will grow in number by 1.7% per year until the year 2015. The amortization fund for chillers will climb accordingly. In the year 2021, 200,000 tons of new chillers will be purchased at a cost of $800/ton x $(1.05)^{30}$. These will amortize at the same rate as before. See Figure 42. The energy required by the new chillers is shown in Figure 43.

Lakewater Pumping System

This plant is considered to come on stream in 1999. The investment will be amortized over 40 years at 10%, e.g., 10.2%/year. In the year 2040 the cost of cooling will drop by the 15¢/ton hr needed to cover the amortization of the plant.

SUMMARY OF INITIAL COST OF LAKEWATER COOLING

The construction of the lakewater system involves time for:

- sufficient engineering design and costing to be able to apply for environmental approval
- time to negotiate the approval
- time to complete enough working documents to call tenders on tunnel drilling
- time to complete construction of tunnels, intake, outfall, pump house, valve chambers and branch lines.

The delay between commencement of design and start up is a cost factor in itself because capital must be sought and interest paid.

Figure 44 describes three construction time schedules. All assume that 1991 will be required to formulate a plan, designate a proponent and secure interim financing.

One schedule, which might be considered optimistic, assumes that public perception of lakewater cooling is positive and that environmental approval can be gained in two years. Some overlap could be considered between environmental approval and engineering as shown. However, tunnelling, which will take 2 1/2 years, even if split into three projects, must await final approval. The pump house can commence connection early if the site is large enough to permit initial excavation to take place away from the wet well. Customer connections will require a year and can be phased to suit the start up of the pumping system.

The base schedule assumes three years for environmental approval while the pessimistic schedule allows six.

System start up is thus planned to take place in mid-1997 for "fast track", January 1999 for the base and January 2002 for "slow track."

The outline of costs for the base case is shown on Figure 45. Assumptions have been made that cost will escalate at 5%/year. A safety factor is built in on the basis that costs which are quoted for 1991 already assume an extended construction period whereas costs are assigned as if further increases must be allowed in each year.

Consulting Fees

The engineering consultant requires 10% of construction cost for design, supervision and commissioning of the system. The fee is thus based on 10% of the projected costs of construction as scheduled to finish in late 1998.

An allowance of $5,000,000 has been made for the first year, during which sufficient design and costing must be done to prepare for environmental scrutiny. Working documents would ensue in the years 1995 and 1996 when environmental approval could be assured. An allowance of a further $3,000,000 has been allocated to supervision and system commissioning.

A further sum, as estimated by Macviro, has been slated to cover the work necessary to carry out the environmental review and to guide the approval process.

A sum of $800,000 has been shown for legal assistance as may be required to secure the pump house site, expedite contract work and deal with liability aspects for customer connections.

Construction

The cost of intake, tunnels, pump house, outfall and valve chambers has been estimated by Proctor & Redfern at $120,000,000. See Appendix B. This however assumes a construction start in 1991.

The cost of branch lines has been estimated by Sayers Assocs. Ltd., mechanical contractors at $3,560,000 including $960,000 for microtunnelling under nine rights of way. See Appendix H. This can be extrapolated to $70,000,000 for the 18 branch lines as described earlier. An alternate scheme, involving microtunnelling for the major tunnelling as described in Appendix B, is also worth $70,000,000.

The sum of these costs is $190,000,000, assuming work is let in 1991. With an allowance for escalation, to a commencement in 1996, the cost of construction has been carried at $243,000,000.

Contingency

This has been assumed at 10% or $24,000,000, on construction only, since the engineering fees can be set without liability for overruns.

Heat Exchangers

Although most of the heat exchangers can be purchased at $75/ton or less for a 1°C approach, this study is allowing $125/ton at 1991 cost. This has been escalated to later purchase for the 228,000 tons which may be available for connection by 1998. The allowance is $33,520,000.

Customer Connections

This has been assumed conservatively, at $400/ton based on 1991 cost. Escalated to 1998, the cost is expected to be $107,200,000.

Heat exchangers, customer connections and customer engineering have been assumed separately because this cost may be funded by the customers themselves.

One scenario is that customers can be given an allowance of:-

Item	1991 Cost
Heat exchangers	$125/ton
Connections	$30/ft. inch
Controls	$30/ton
Design Engineer	$45/ton

These allowances, if funded by the proponent, would safely cover the customer's cost while adjusting fairly for the wide differences in piping length and for hydraulic anomalies. The customer would be still totally responsible for design and any problems with his own connection. The owner could purchase a heat exchanger at $50/ton with a 3°C approach, for instance, or indulge in luxury control and instrumentation at his own discretion.

Customer Engineering

Most of the HVAC engineers in town would become involved in this. A fee of 7 1/2% of customer work has been allowed.

Taxes

Although 8% PST is not normally charged on engineering, taxes have been allowed, across the board, for 8% PST and 7% GST.

Interim Finance

It has been assumed that money is borrowed at 10% to finance all of the costs during installation.

The final cost, as shown in Figure 45, is $611,000,000, of which $98,800,000 is interim finance.

A reckoning of the major costs is as follows:

Item	$ (incl. financing)
Consulting & legal	42,500,000
Construction, incl. contingency	323,000,000
Customer connections, inc.engrg.	166,000,000
Taxes	79,500,000
Total	611,000,000

Ontario Hydro Incentive

Ontario Hydro provides an incentive of $400/kW avoided by thermal storage.

If this is escalated to the year 1998 and applied to 228,875 kW of connected cooling load, the incentive would be $135,265,000.

The net cost would then become $611,006,800 - $135,265,000 or $475,751,800.

A rerun of Figure 47, a spreadsheet showing the base cost of lakewater cooling, is shown in Figure 51. This defines the cost per ton hour, the total cost and the present value of a system if the Ontario Hydro incentive were withheld along with a drop in usership of 25%. The cost per ton hour is also defined graphically on Figure 49 as another sensitivity analysis.

ECONOMIC COMPARISON OF ON SITE CHILLERS WITH LAKEWATER COOLING

Spreadsheet Analysis 1991-2040

- Assumptions

It has been assumed that the economics of the lakewater system should be tested over a 40 year period as would be the case with an Ontario Hydro generating plant. It has also been assumed that debentures can be sold at 10% for a 40 year period. This term could be questioned since the cost per ton hour would only be increased by 2/3¢ if the period was reduced to 30 years. Discussion is needed as far as this aspect of financing is concerned.

The cost per ton hour is assumed to include amortization of the hardware necessary to supply cooling. In the case of on site chillers, this entails amortization of the existing 200,000 tons over 30 years plus the amortization of new chiller purchases including repurchase of the original chillers in the year 2021. The lakewater cooling amortization includes all the costs shown on Figure 45 plus the amortization of new heat exchangers purchased after 1998. See Figure 42.

Cooling load in 1991, of 200,000 tons, is increased by 1.7% to a final load of 300,000 tons in 2015. Usership is based on 80% central systems with 1160 full load hrs/year and 20% compartmented systems at 1875 full load hrs/year. The compartmented systems are growing in popularity despite a lower ability to do winter free cooling. This is because they have the potential to return enough mechanical and shaft space to rental to retire their initial cost with the present value of future rent. If the ratio of these systems is higher today, or trends higher with the addition of the new 100,000 tons of cooling, the cost per ton hour will drop along with the sale of more ton hours per ton connected. This is true even if the compartmented systems incorporate waterside free cooling. There are many hours between 5°C and 15°C when airside free cooling operates for central systems but waterside free cooling cannot yet function for compartmented systems. See Figure 3. The result of an increase to 50% of the ratio of compartmented systems is a sale of 60,000,000 more ton hours/year and a drop in the cost/ton hour of up to 4¢.

- Printout

Figure 46 is a spread sheet which details the energy cost for on site chillers as derived from Figures 29, 30 31, 32 and 43. It also includes the cost of servicing the chillers and water towers.

The result is a rise in cost per ton hour from 23¢ in 1991 to $1.98 in 2040. The overall cost in the comparison period is $14,679,781,000 and the present worth of this expense stream is $1,696,876,000.

Figure 47 compiles lakewater energy from Figures 37 and 38 with servicing cost, and amortization of original plant, from Figure 45, plus new heat exchangers. No allowance is made for customer connections for future plants since this is unnecessary in a new building.

The result is a rise in cost per ton hour from 16.5¢ to 21¢ in 2039, then a drop to 9¢ in 2040 as the amortization of original investment is cleared. The overall cost in the 1999 to 2040 period is $2,533,186,000 and the present worth of this expense stream is $471,027,000.

The lakewater system is thus seen to be $12,146,595,000 less expensive than the cost of on site cooling and $1,225,849,000 less expensive in present worth.

Figure 48 describes this difference graphically.

Sensitivity Analysis

Much can change in the undertaking of a large project. Some of the possible scenarios have been examined with a computer program.

- Slow Customer Connection

Figure 49 shows the comparison of cost/ton hour of on site cooling with the base case. Despite an expected saving of 14 1/2¢/ton hour, over on site chillers, in the cost of cooling, it is assumed that only 50% of the eligible 228,875 tons will connect. By 2005 when the difference has risen to 24¢/ton hr, another 25% will connect. The 25% final holdouts will connect when they see the spread increased to 35¢/ton hour in the year 2010.

This produces an odd cost configuration distorted by large Ontario Hydro incentives when the delayed customers finally connect. If the high initial cost of some years is massaged financially, the curve can be regulated to show little difference to the base case. The aggregate cost will drop, however, to $2,437,200,000 and the present worth to $421,230,000.

- Construction Cost Overrun

  This has been allowed at 15% for the system and 25% for customer connections. The result is a 3¢/ton hour increase as shown on Figure 49. The aggregate cost will rise to $2,898,100,000 and the present worth to $551,900,000. A second assumption, see Figure 52, assumes the unlikely chance that the initial cost will be overrun by 100% along with a drop in usership by 25%. Even in this case the aggregate cost is 5.1 Billion dollars compared to 15.3 Billion dollars for chillers while the present worth is 1.05 Billion dollars compared to 1.7 Billion dollars.

- Extended Construction Period (Slow Track)

  The three year approval delay will cost 2¢/ton hour initially and 3 1/2¢/ton hour at the end of the period. This will raise the aggregate cost to $2,882,100,000 and the present worth to $631,400,000.

  The "fast track" will lower costs by an average of 1¢/ton hour as shown on Figure 49.

- Low Usage

  The base case assumes 1160 full load hours for central systems and 1875 full load hours for compartmented systems. The blended average is 1303 FLH. If the average is only 1000 FLH, after all, (890 FLH central 1439 compartmented), the cost per ton hour will rise from 16.4¢to 24¢ in 1999. However, if cooling usage is lower, it will also affect the on site chiller cost. This will rise from 31¢/ton hr to 38¢/ton hour.

- Profit Opportunity

  If the cost of lakewater cooling is allowed to escalate at the same 5%/year as electricity and other services, a profit of some $6,500,000,000 will accrue. This could be applied to other worthwhile environmental concerns. See Figure 50.

Computer Printouts

The spreadsheets for the alternate scenarios are included in Appendix G.

Summary of Safety Factors

Large projects have a well known tendency for cost overruns. This project is bound to have its share. In order to be as conservative as possible, the following assumptions were made to provide a margin of safety:

- Chilled Water Range

  This is assumed to be 6.7°C. It may be a high as 8.33°C particularly if the rate of charge rewards those with a high range. This increase would allow the same volume of water to do 25% more cooling.

- Construction Cost

  This is assumed to start in 1996 and escalate in each year thereafter. In reality the estimates received in 1991 take the time escalation into account. Thus the $260,000,000 allowance may be higher by 30,000,000 than the bids expected in 1995.

- Heat Exchanger Allowance

  These can be purchased for a 1°C approach for prices between $75 and $90/ton depending on the hydraulic pressure requirement. The allowance is $125/ton. This provides a margin of safety of $10,000,000.

- Customer Connection Allowance

  Piping has been costed at $30/ft. inch vs $10/ft. inch allowed for new construction and $14/ft. inch bid by Sayers on the King-Wellington headers ($18/ft. inch including microtunnelling). This provides a margin of safety of up to $20,000,000.

- Taxes

  8% PST does not apply to labour so there has been double counting on PST for consulting fees and construction labour. This safety factor in the estimate amounts to 8% of $84,000,000 or $6,700,000.

- Contingency

  An allowance of $24,000,000 is included for construction.

- Total

The sum of contingencies including taxes on contingencies is approximately $100,000,000 or 16% of the $611,000,000 total cost.

Figure 1
Freecool Layout

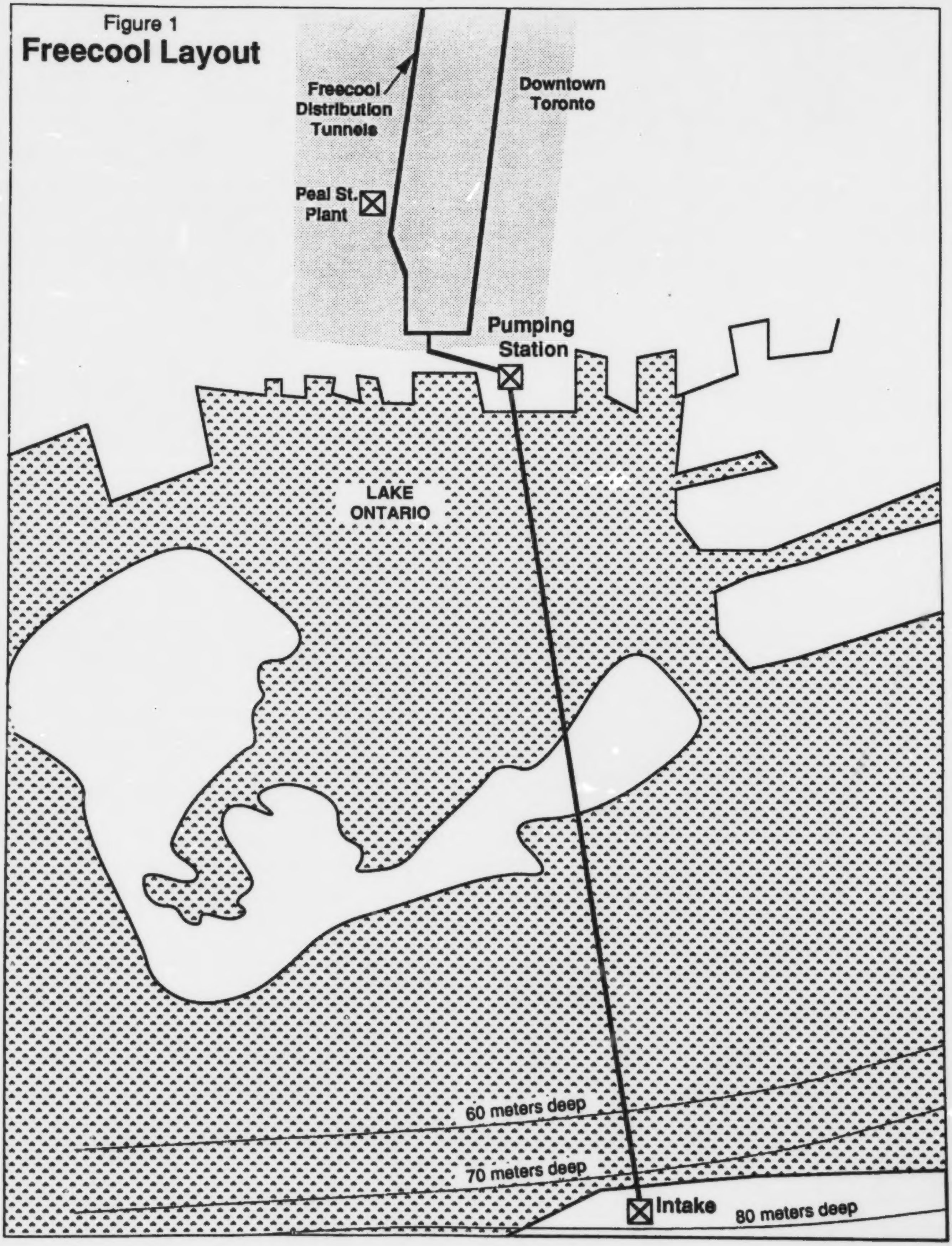

Freecool Distribution Tunnels
Downtown Toronto
Peal St. Plant
Pumping Station
LAKE ONTARIO
60 meters deep
70 meters deep
Intake
80 meters deep

Figure 2

100 % Probability Curves for Lakewater Temperature

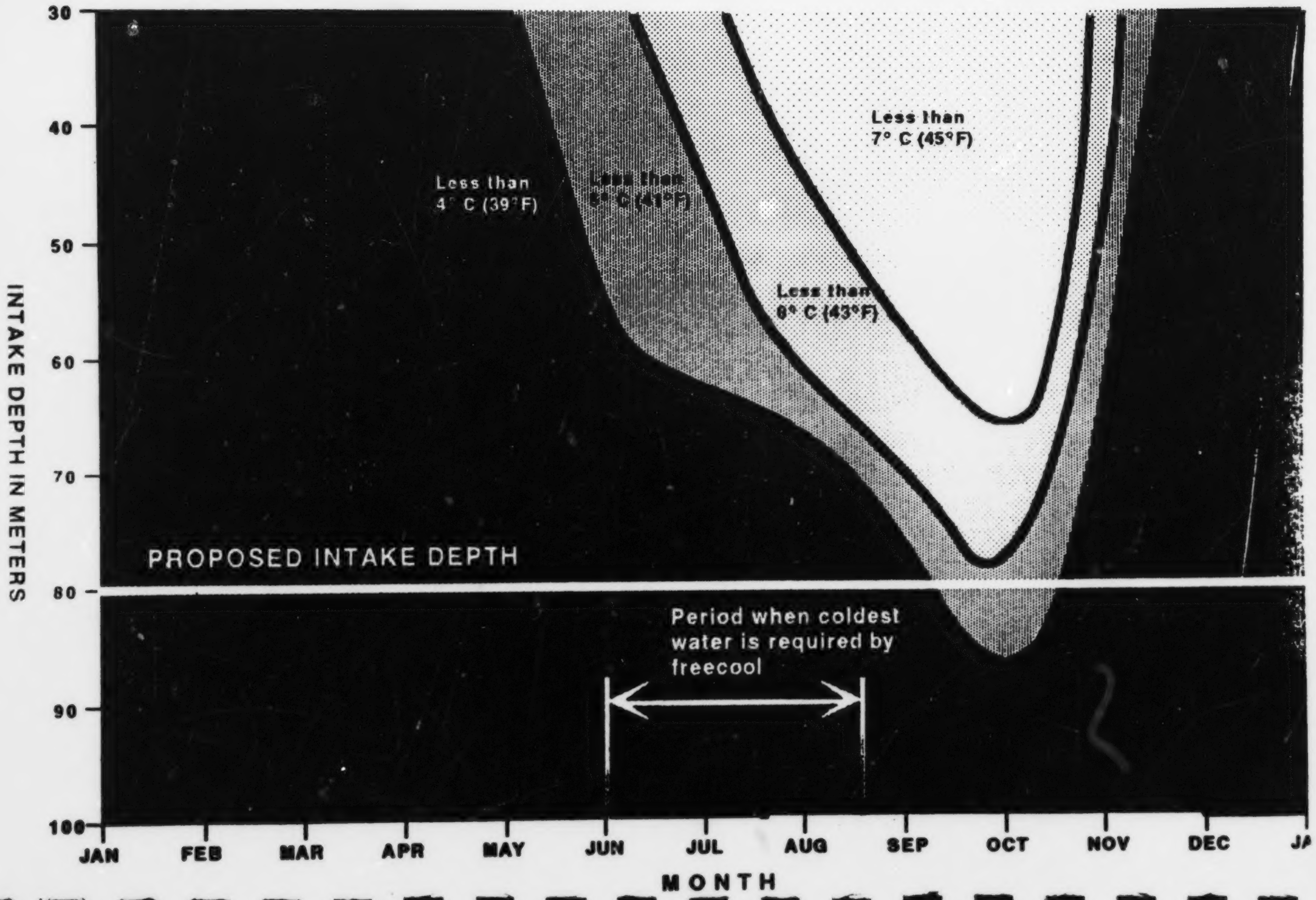
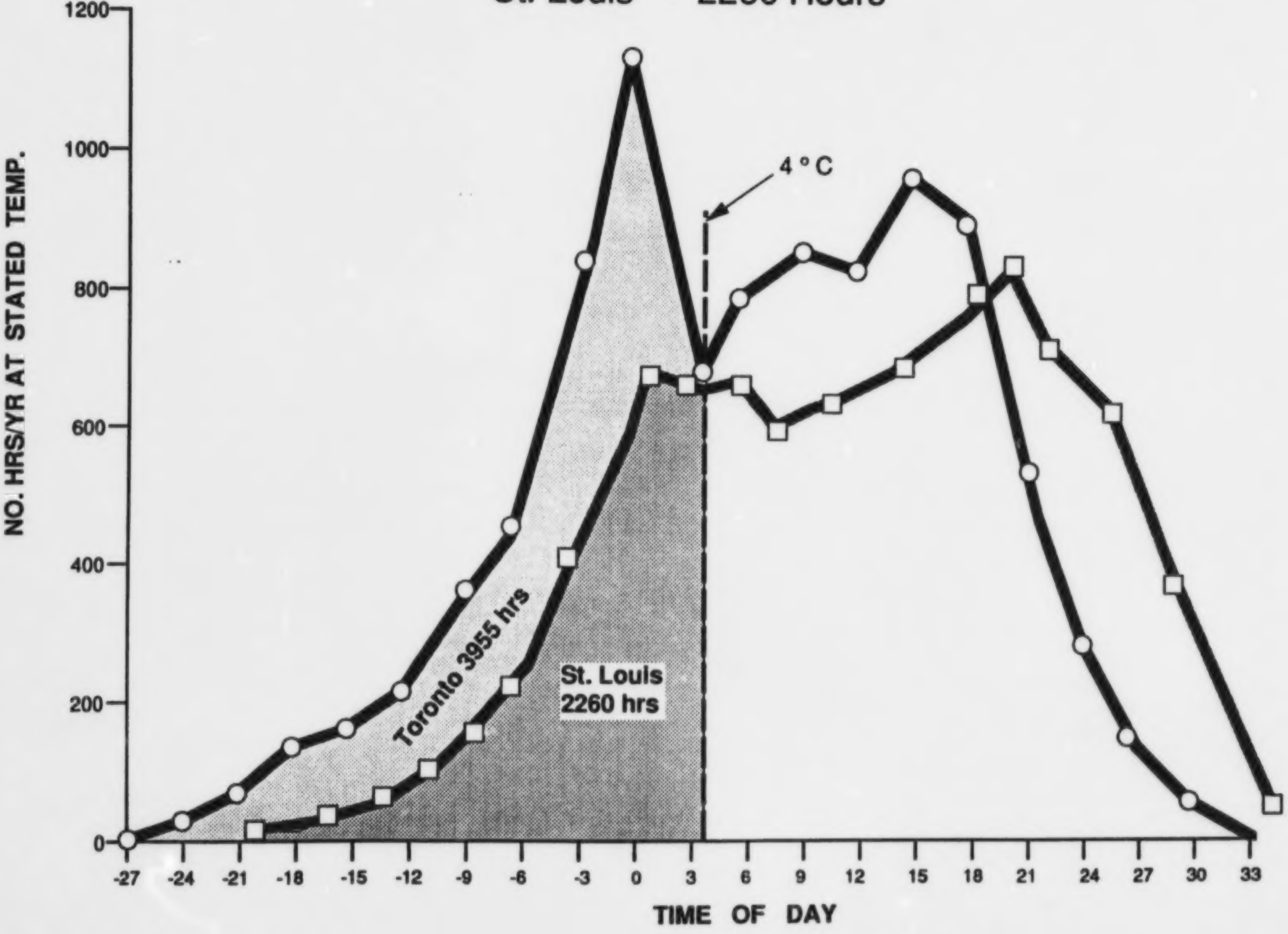
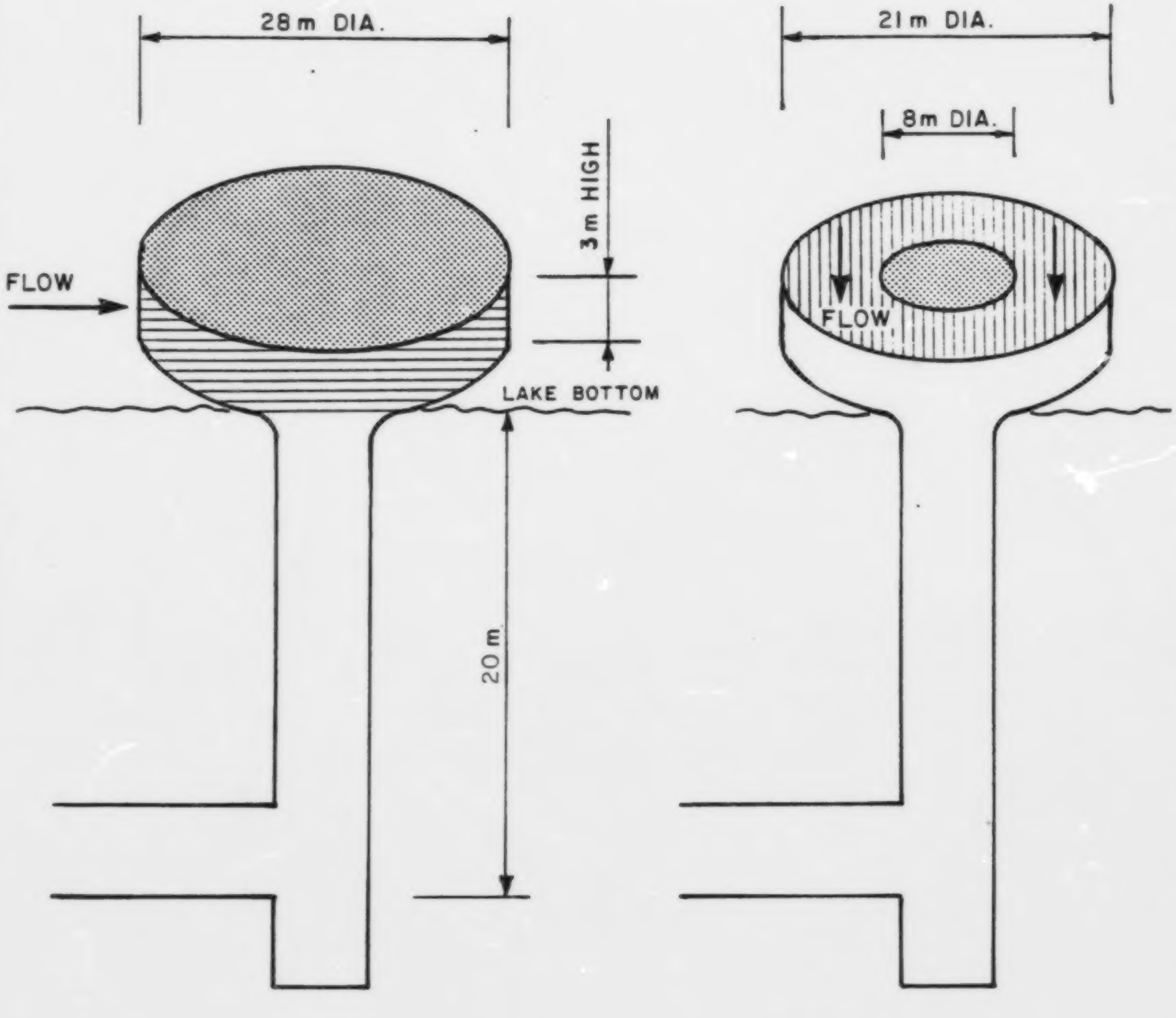


Figure 3

Hours/Year Below 4 ° C

Toronto - 3955 Hours
St. Louis - 2260 Hours

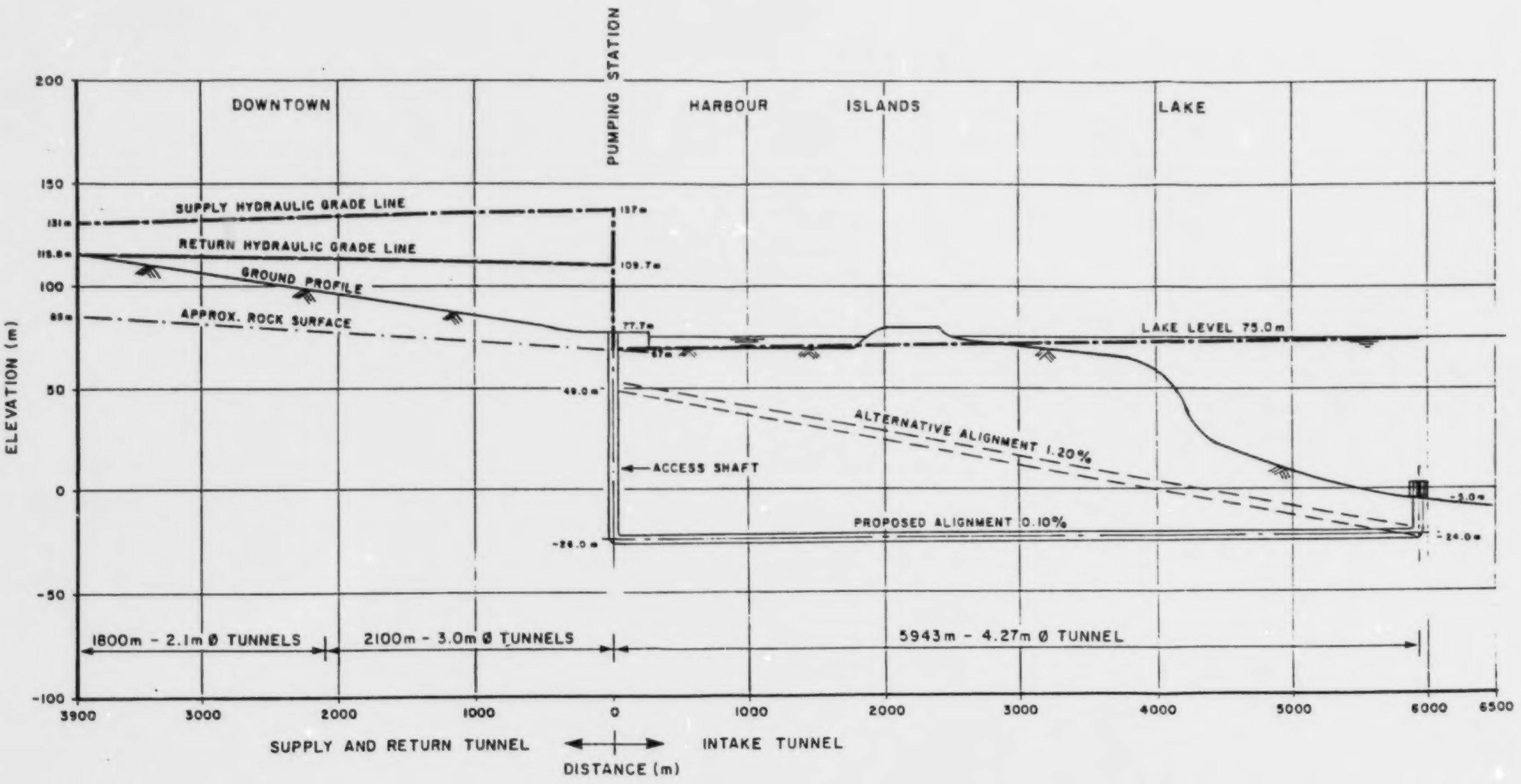



28m DIA.
3m HIGH
FLOW
LAKE BOTTOM
20 m
21m DIA.
8m DIA.
FLOW

HORIZONTAL FLOW
VERTICAL INTAKE

DOWNWARD FLOW
HORIZONTAL INTAKE

Drawn by	DEEP LAKE WATER COOLING DOWNTOWN TORONTO	Proctor & Redfern Limited Consulting Engineers & Architect Toronto	
Ckd. by	LAKE INTAKE CRIB	Scale	Date APRIL 1991
		E.O. 91115	FIGURE 4

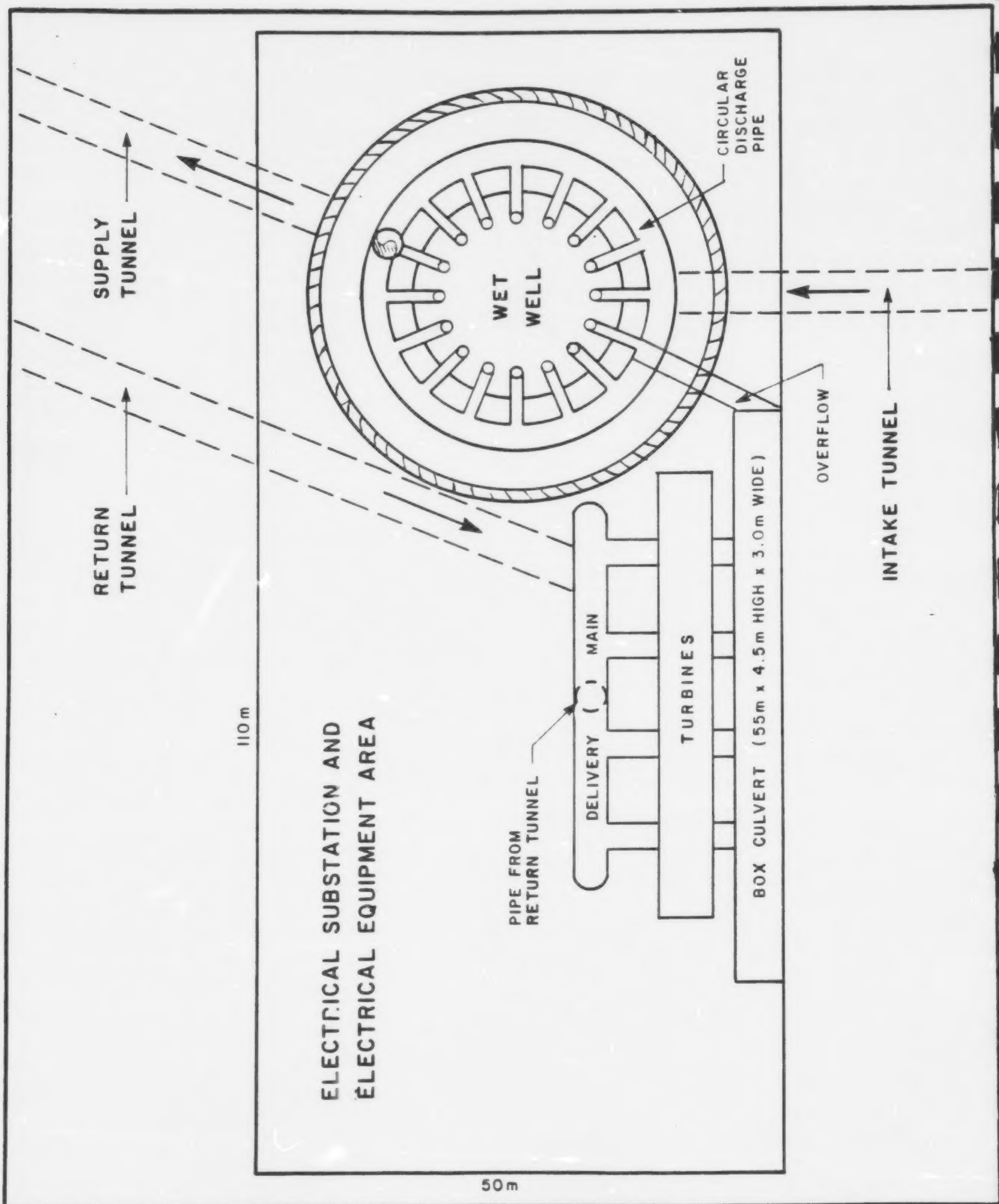

PUMPING STATION
DOWNTOWN
HARBOUR
ISLANDS
LAKE
200
150
100
50
0
-50
-100
ELEVATION (m)
SUPPLY HYDRAULIC GRADE LINE
RETURN HYDRAULIC GRADE LINE
GROUND PROFILE
APPROX. ROCK SURFACE
131m
115.8m
85m
137m
109.7m
77.7m
67m
49.0m
-26.0m
LAKE LEVEL 75.0m
ALTERNATIVE ALIGNMENT 1.20%
ACCESS SHAFT
PROPOSED ALIGNMENT 0.10%
-3.0m
-24.0m
1800m - 2.1m Ø TUNNELS
2100m - 3.0m Ø TUNNELS
5943m - 4.27m Ø TUNNEL
3900
3000
2000
1000
0
1000
2000
3000
4000
5000
6000
6500
SUPPLY AND RETURN TUNNEL
INTAKE TUNNEL
DISTANCE (m)

DEEP LAKE WATER COOLING
DOWNTOWN TORONTO

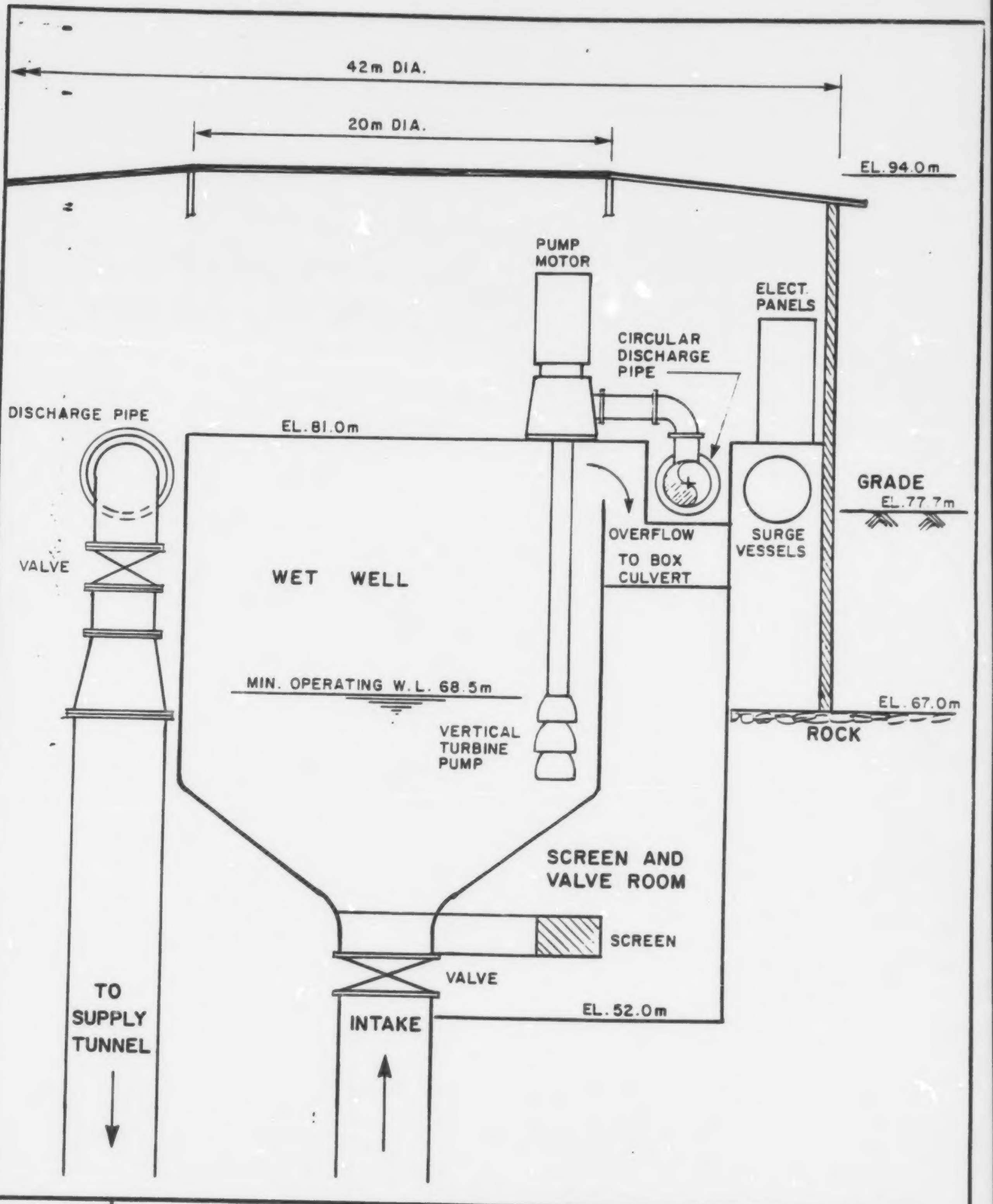
ROUTE I - LONGITUDINAL SECTION
AT 37.8m³/s FLOW RATE

Proctor & Redfern Limite
Consulting Engineers and Architect
Toronto

Scale
Date: APRIL 1991
Drawn By
Chk By
E.O. 91115
FIGURE 5


SUPPLY TUNNEL
RETURN TUNNEL
CIRCULAR DISCHARGE PIPE
WET WELL
OVERFLOW
INTAKE TUNNEL
BOX CULVERT (55m x 4.5m HIGH x 3.0m WIDE)
TURBINES
DELIVERY MAIN
PIPE FROM RETURN TUNNEL
ELECTRICAL SUBSTATION AND ELECTRICAL EQUIPMENT AREA
110m
50m

Drawn by	DEEP LAKE WATER COOLING DOWNTOWN TORONTO	Proctor & Redfern Limited Consulting Engineers & Architect Toronto	
Ckd. by	MAIN PUMPING & ENERGY RECOVERY STATION - PLAN VIEW	Scale	Date APRIL 1991
		E.O. 91115	FIGURE 6


42m DIA.
20m DIA.
EL. 94.0m
PUMP MOTOR
ELECT. PANELS
CIRCULAR DISCHARGE PIPE
DISCHARGE PIPE
EL. 81.0m
GRADE
EL. 77.7m
OVERFLOW
TO BOX CULVERT
SURGE VESSELS
VALVE
WET WELL
MIN. OPERATING W. L. 68.5m
EL. 67.0m
ROCK
VERTICAL TURBINE PUMP
SCREEN AND VALVE ROOM
SCREEN
VALVE
TO SUPPLY TUNNEL
INTAKE
EL. 52.0m

Drawn by

Ckd. by

DEEP LAKE WATER COOLING
DOWNTOWN TORONTO

MAIN PUMPING STATION
ELEVATION

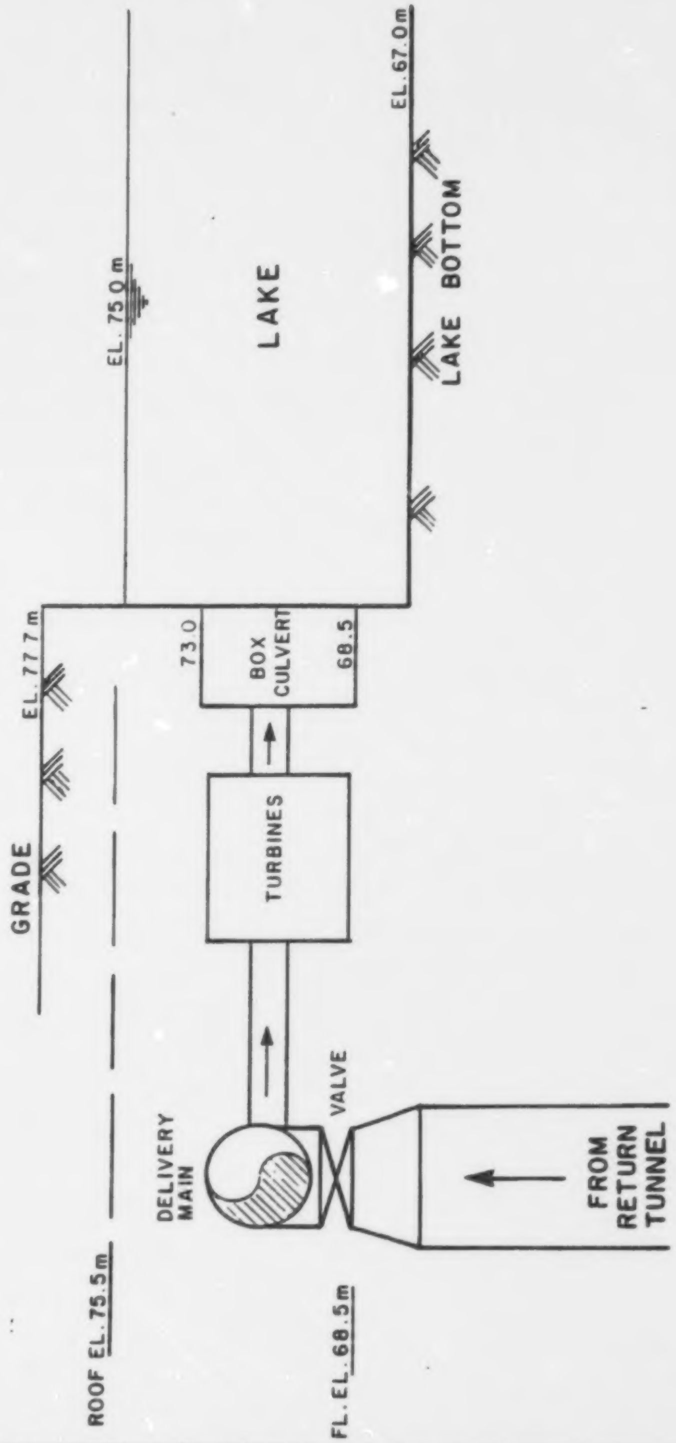
Proctor & Redfern Limited
Consulting Engineers & Architect
Toronto

Scale

Date APRIL 1991

E.O. 91115

FIGURE 7


EL. 67.0m
LAKE BOTTOM
LAKE
EL. 75.0m
EL. 77.7m
GRADE
73.0
BOX CULVERT
68.5
TURBINES
VALVE
DELIVERY MAIN
FROM RETURN TUNNEL
ROOF EL. 75.5m
FL. EL. 68.5m

Drawn by	DEEP LAKE WATER COOLING DOWNTOWN TORONTO	**Proctor & Redfern Limited** Consulting Engineers & Architect Toronto	
Ckd. by	ENERGY RECOVERY GALLERY INCLUDING OUTFALL BOX CULVERT	Scale	Date APRIL 1991
		E.O. 91115	FIGURE B

Figure 9

Freecool Grid

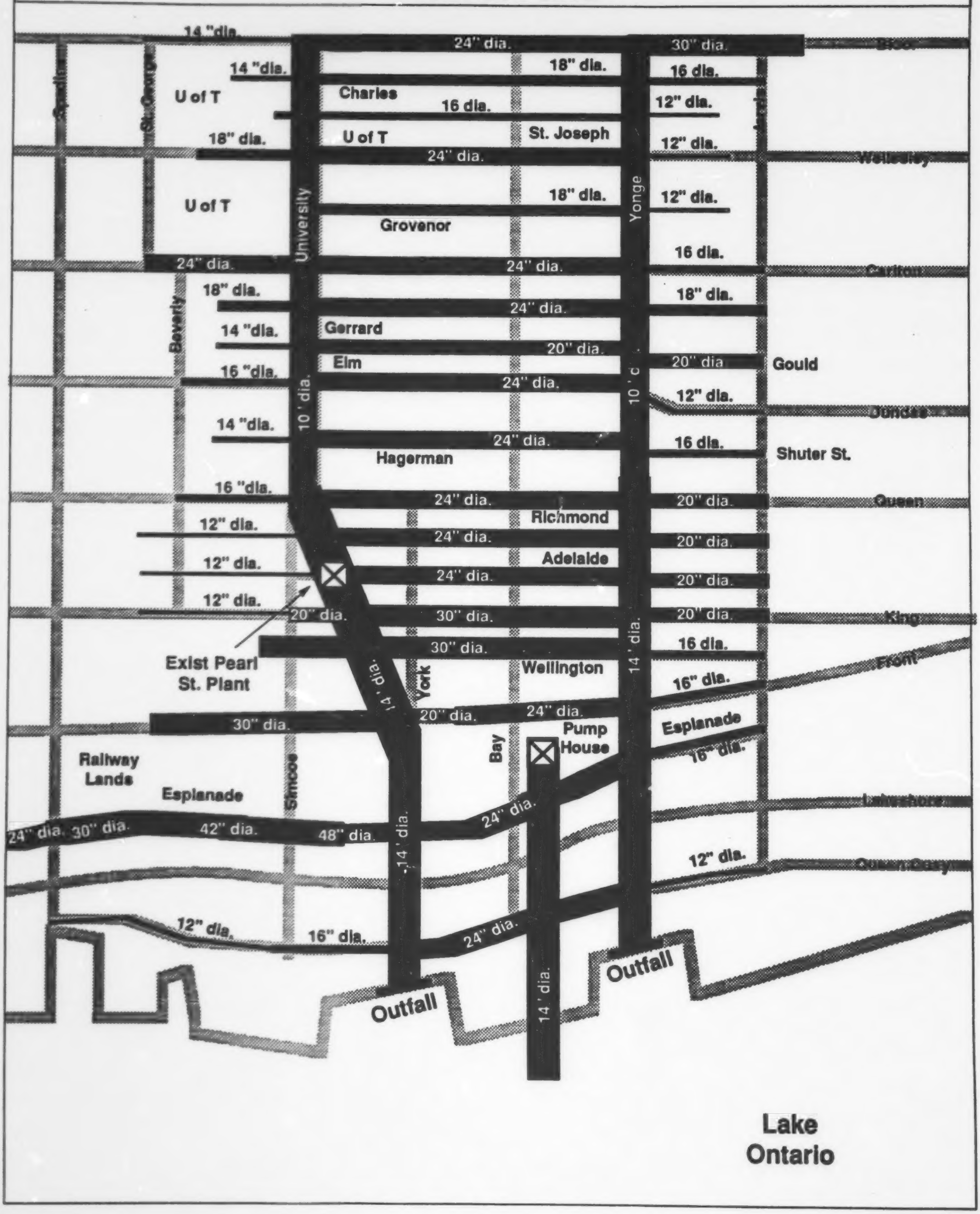

14 "dia.
24" dia.
30" dia.
Bloor
14 "dia.
18" dia.
16 dia.
Spadina
St. George
U of T
Charles
16 dia.
12" dia.
Jarvis
18" dia.
U of T
St. Joseph
12" dia.
24" dia.
Wellesley
U of T
University
18" dia.
12" dia.
Grovenor
Yonge
16 dia.
24" dia.
24" dia.
Carlton
18" dia.
18" dia.
Beverly
24" dia.
14 "dia.
Gerrard
20" dia.
20" dia
Gould
16 "dia.
Elm
24" dia.
10 ' dia.
10 ' d
12" dia.
Dundas
14 "dia.
24" dia.
16 dia.
Shuter St.
Hagerman
16 "dia.
24" dia.
20" dia.
Queen
Richmond
12" dia.
24" dia.
20" dia.
Adelaide
12" dia.
24" dia.
20" dia.
12" dia.
20" dia.
30" dia.
20" dia.
King
30" dia.
16 dia.
Exist Pearl St. Plant
14' dia.
York
Wellington
14' dia.
Front
16" dia.
20" dia.
24" dia.
30" dia.
Pump House
Esplanade
Bay
16" dia.
Railway Lands
Esplanade
Simcoe
Lakeshore
24" dia.
24" dia.
30" dia.
42" dia.
48" dia.
14' dia.
12" dia.
Queens Quay
12" dia.
16" dia.
24" dia.
14' dia.
Outfall
Outfall
Lake Ontario

Figure 10

Longitudinal Section From Queens Quay To Bloot Street Showing Ground, Water and Bedrock Levels

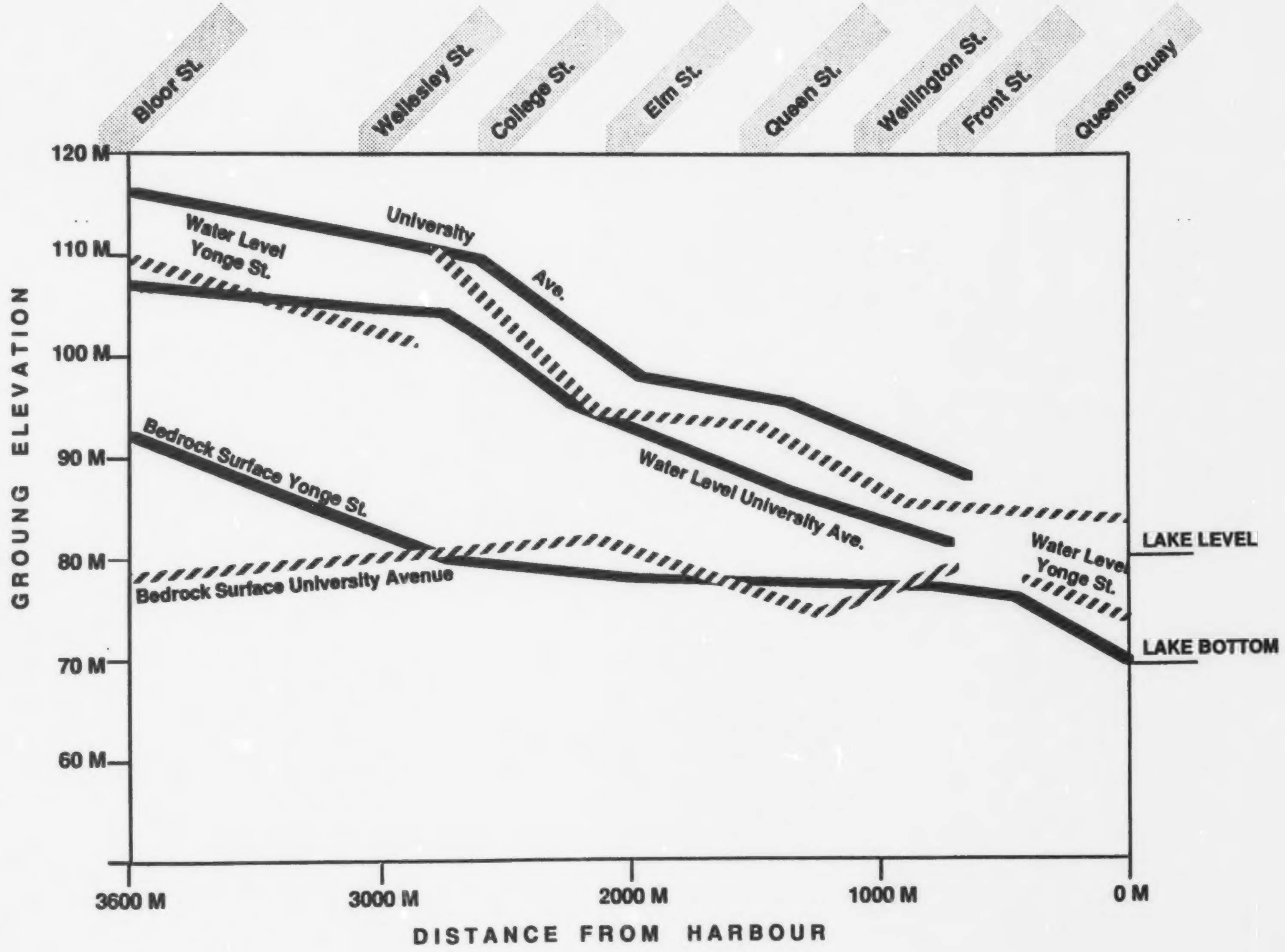


Figure 11

Plan of King Wellington Branch Line

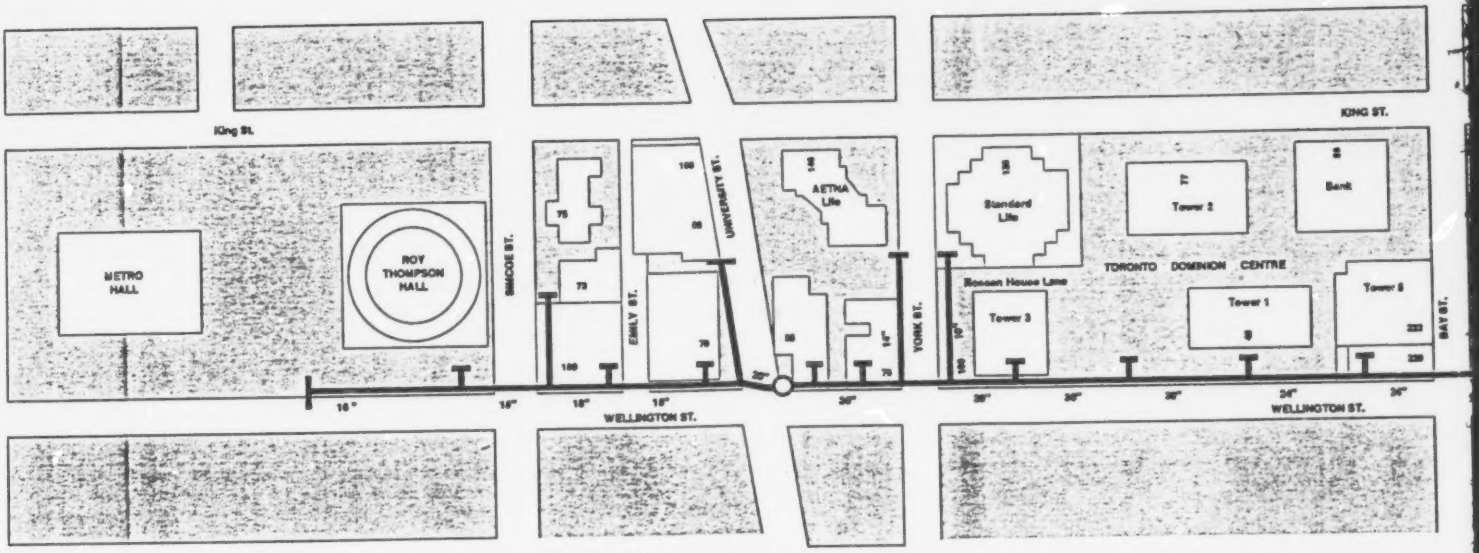
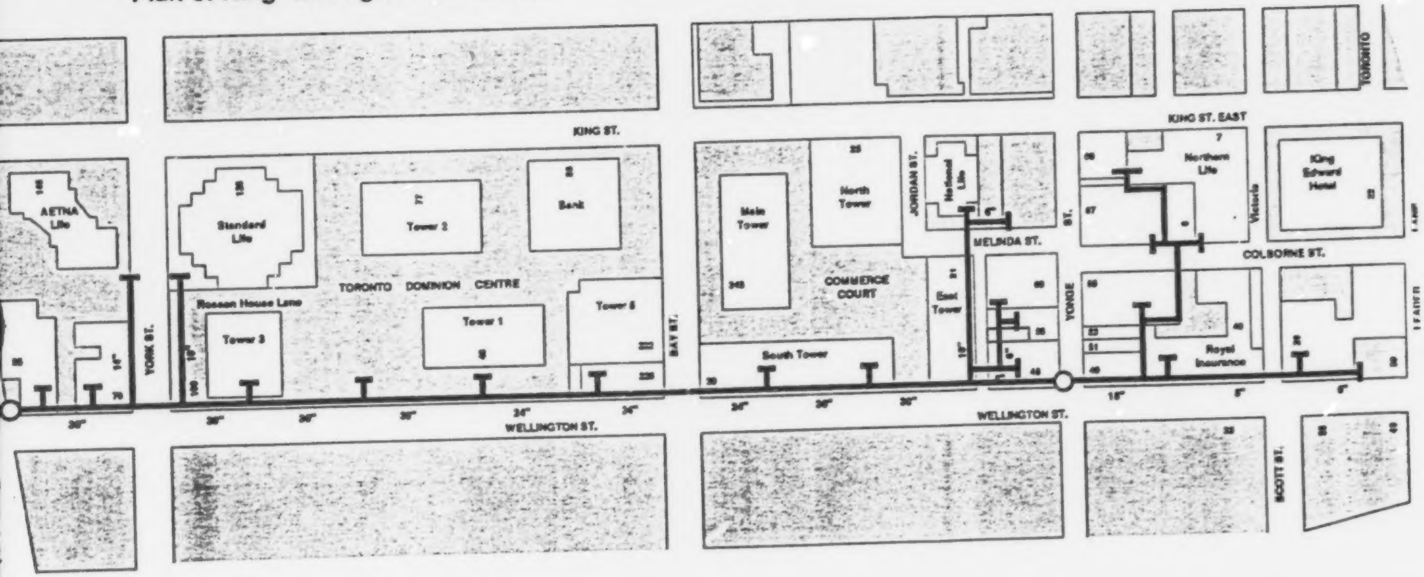
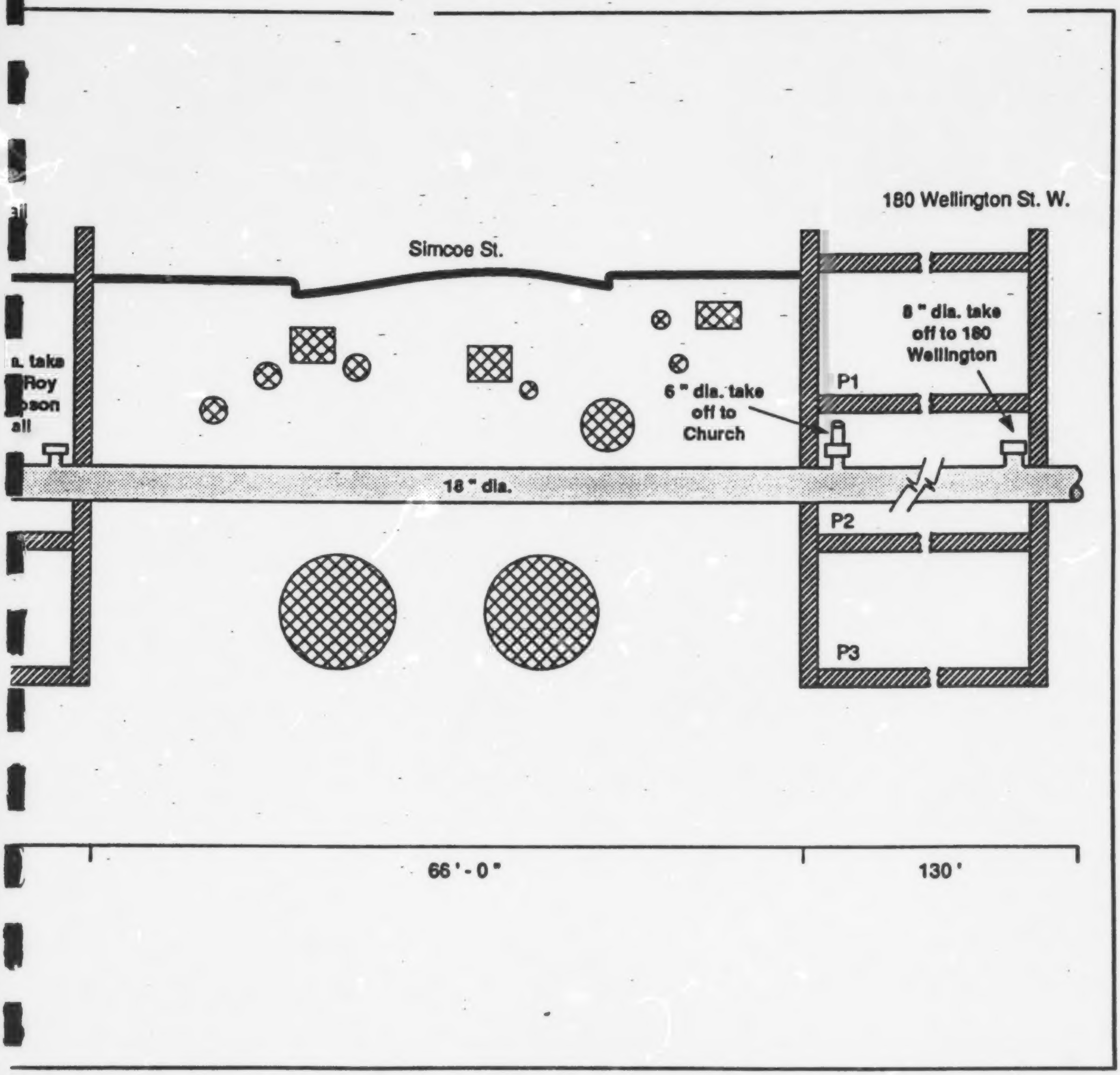
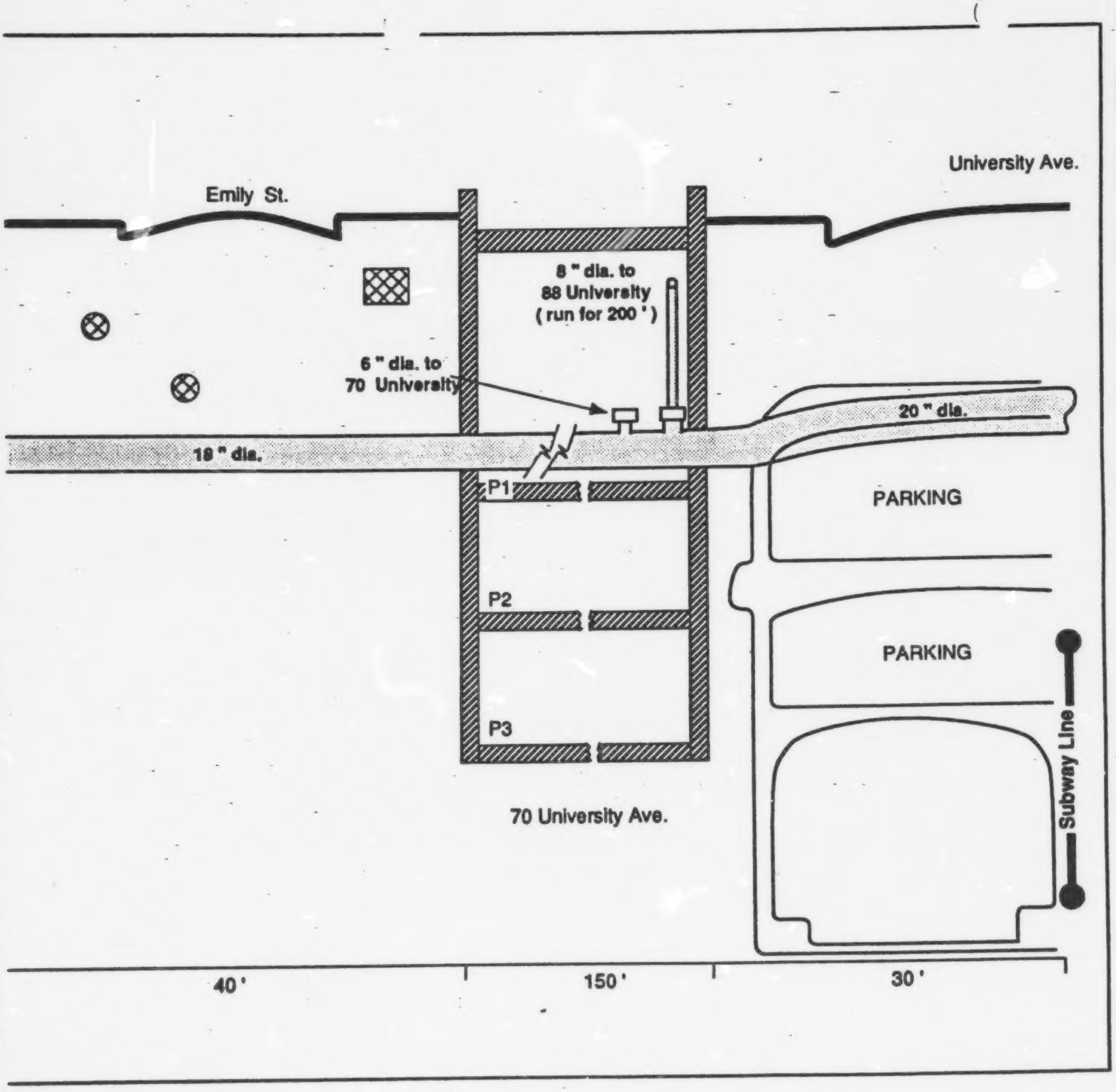

King St.
KING ST.
METRO HALL
ROY THOMPSON HALL
SIMCOE ST.
75
73
100
EMILY ST.
100
70
UNIVERSITY ST.
AETNA Life
55
14"
70
YORK ST.
Standard Life
Tower 3
Tower 2
77
Bank
TORONTO DOMINION CENTRE
Tower 1
Tower 5
222
BAY ST.
16"
16"
16"
16"
20"
30"
36"
36"
36"
24"
36"
WELLINGTON ST.
WELLINGTON ST.

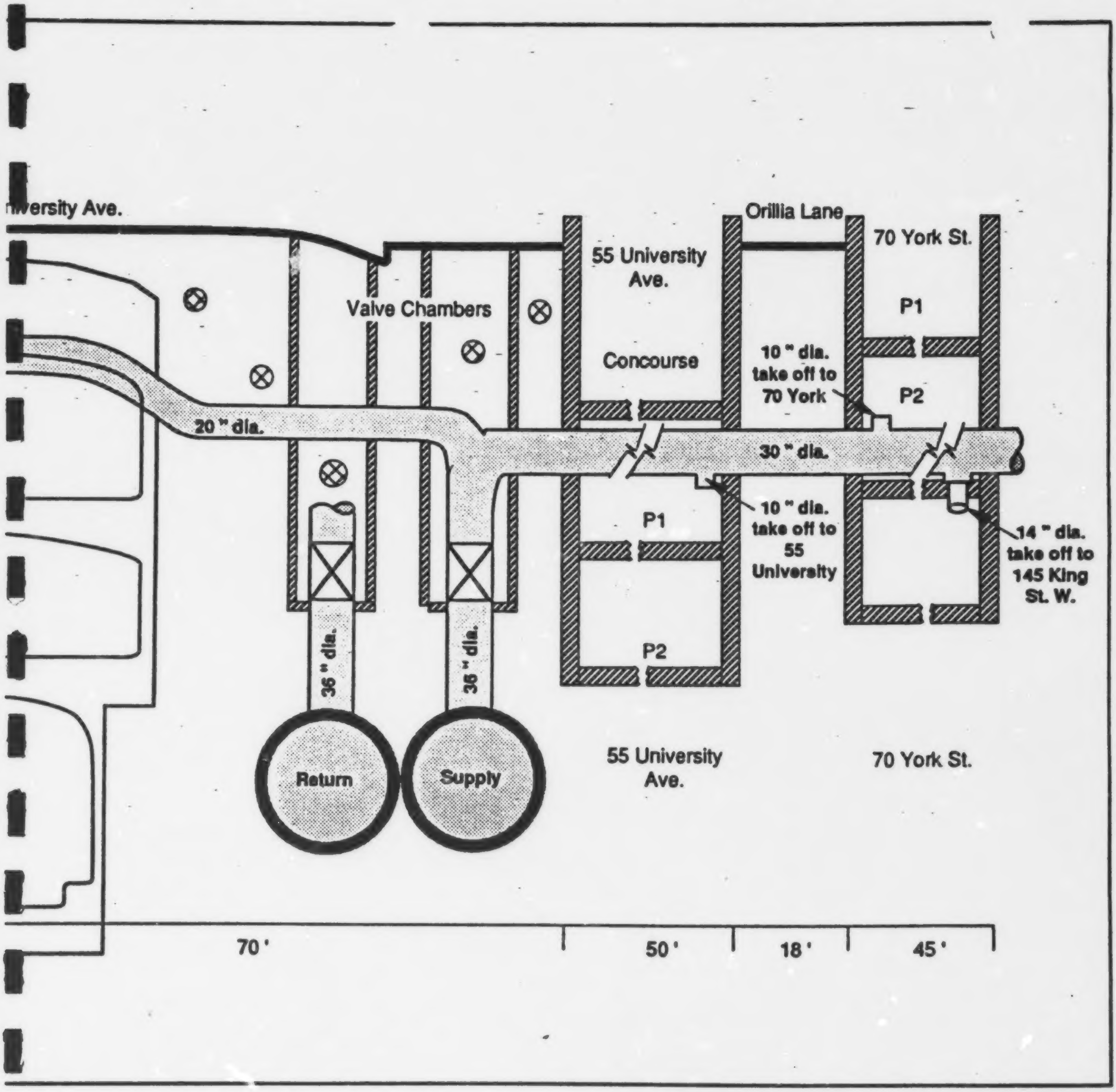
Figure 11

Plan of King Wellington Branch Line


KING ST.
KING ST. EAST
TORONTO
AETNA Life
Standard Life
Tower 2
Bank
TORONTO DOMINION CENTRE
Rosson House Lane
Tower 3
Tower 1
Tower 5
YORK ST.
BAY ST.
Main Tower
North Tower
COMMERCE COURT
South Tower
JORDAN ST.
National Life
East Tower
MELINDA ST.
YONGE ST.
Northern Life
Victoria
King Edward Hotel
COLBORNE ST.
Royal Insurance
WELLINGTON ST.
SCOTT ST.
36"
30"
24"
18"
8"
6"
14"
10"

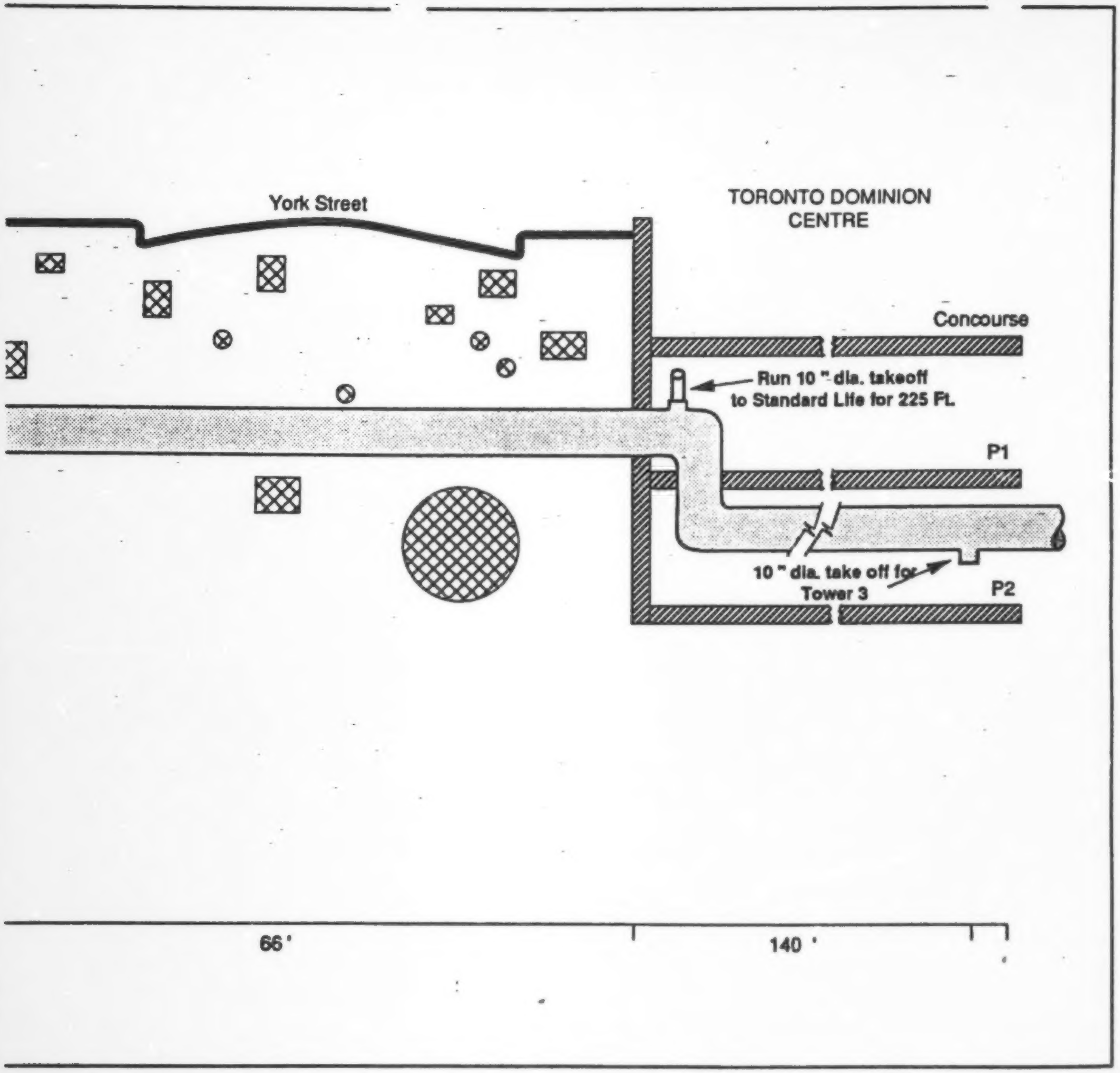

180 Wellington St. W.
Simcoe St.
8 " dia. take off to 180 Wellington
a. take
Roy
pson
all
all
P1
6 " dia. take off to Church
18 " dia.
P2
P3
66 ' - 0 "
130 '

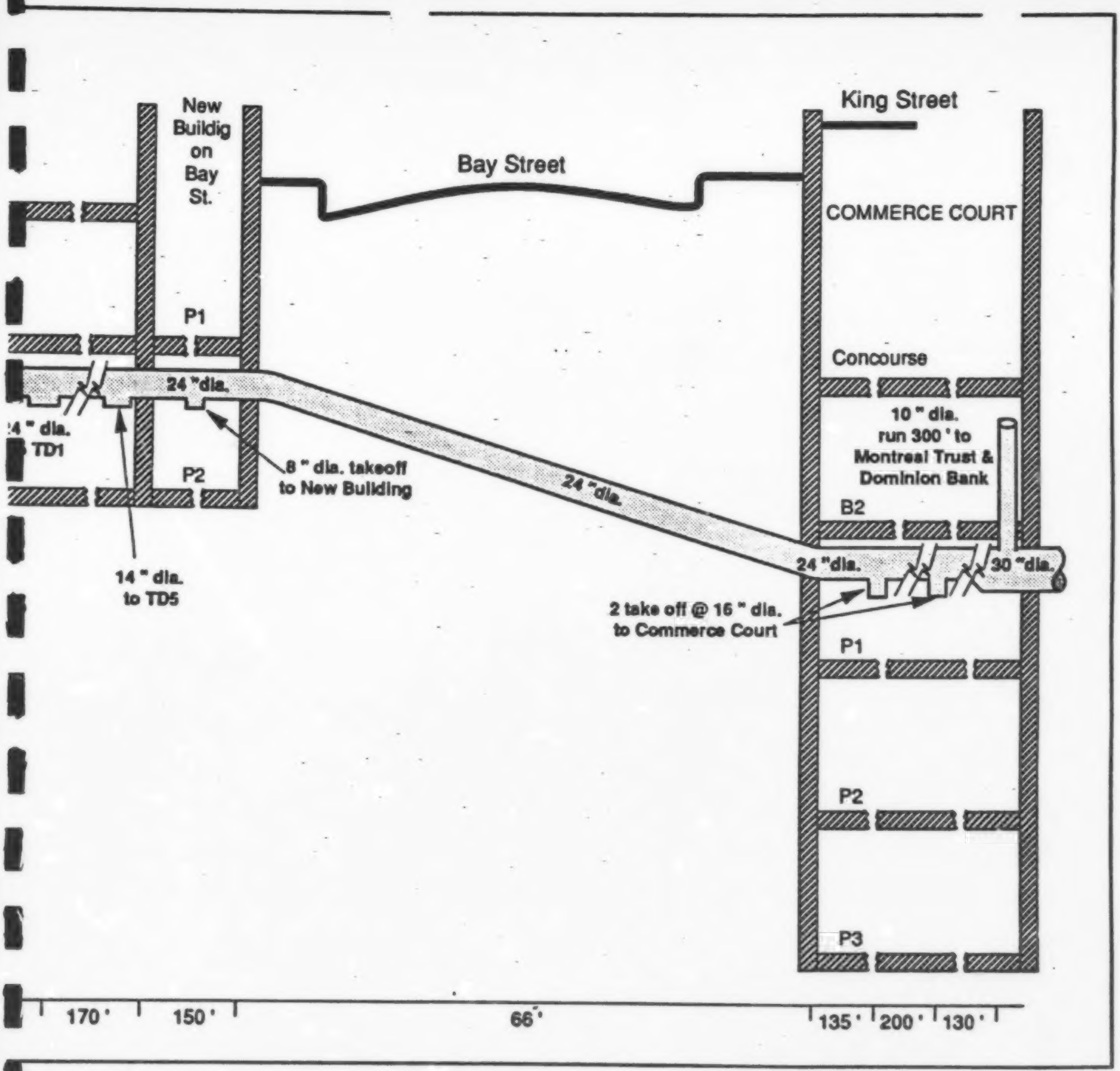

University Ave.
Emily St.
8 " dia. to
88 University
(run for 200 ')
6 " dia. to
70 University
20 " dia.
18 " dia.
P1
P2
P3
PARKING
PARKING
Subway Line
70 University Ave.
40 '
150 '
30 '

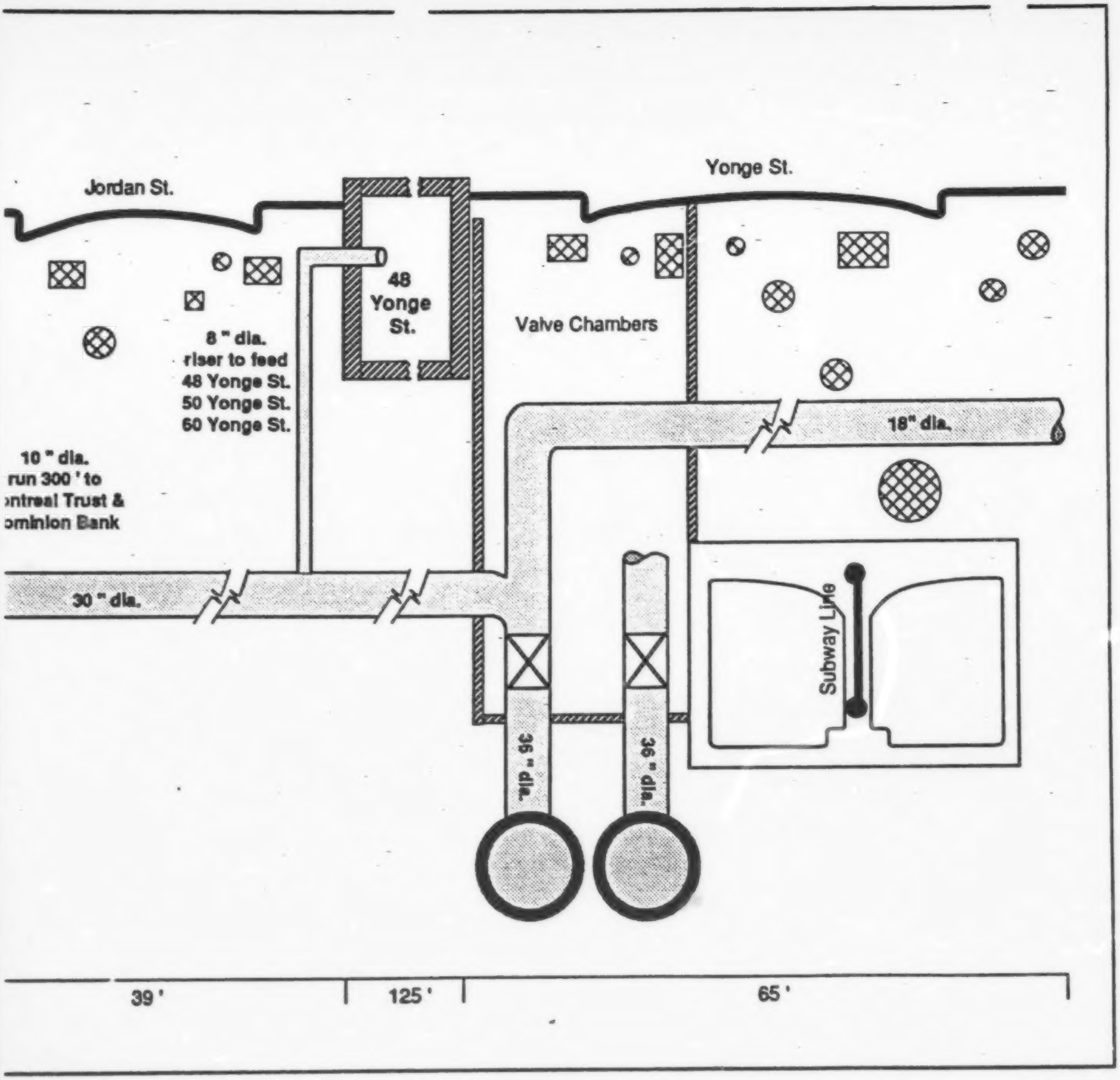


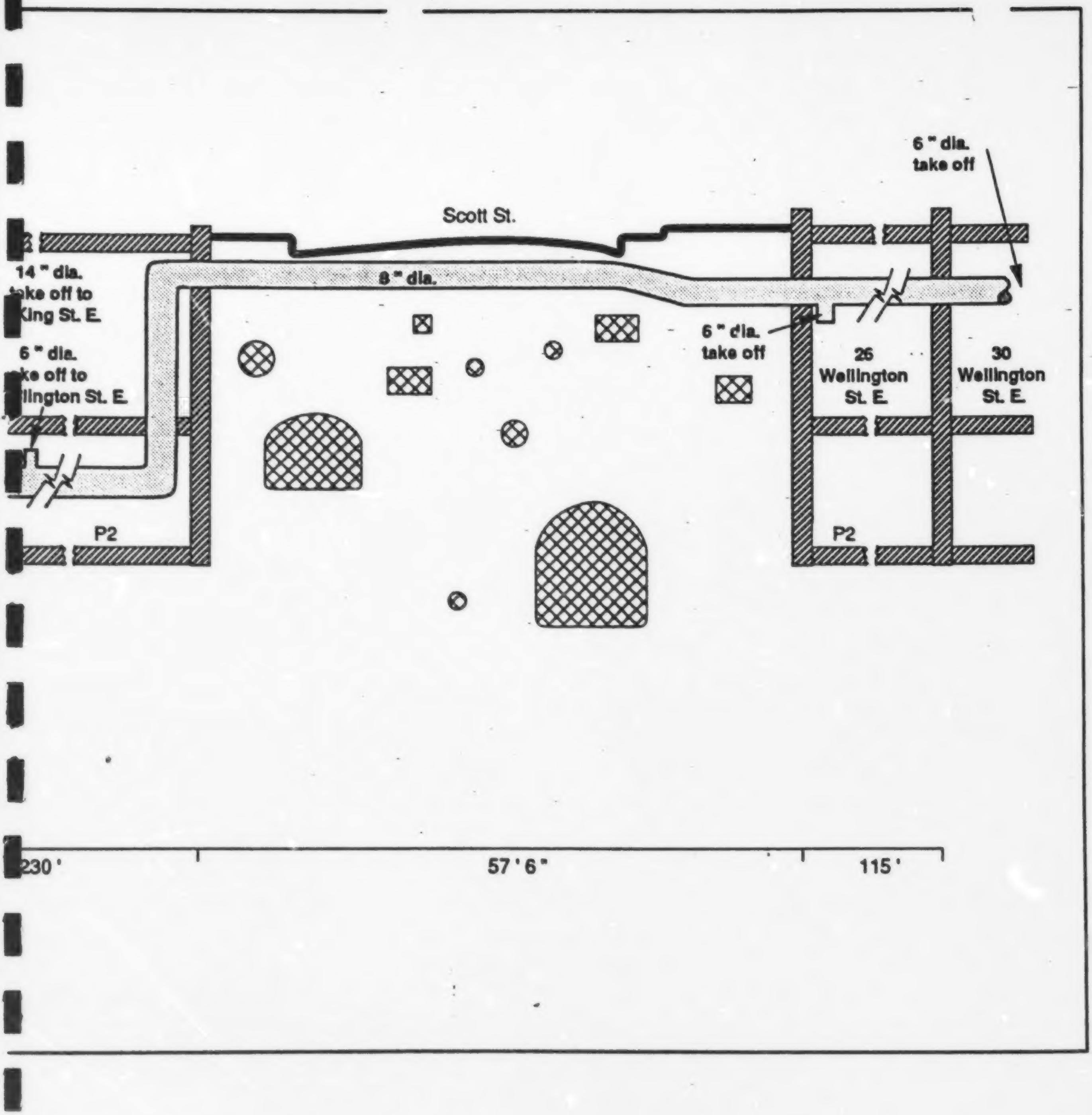
versity Ave.
Orillia Lane
70 York St.
55 University Ave.
Valve Chambers
P1
Concourse
10" dia. take off to 70 York
P2
20" dia.
30" dia.
P1
10" dia. take off to 55 University
14" dia. take off to 145 King St. W.
36" dia.
36" dia.
P2
Return
Supply
55 University Ave.
70 York St.
70'
50'
18'
45'

12c


York Street
TORONTO DOMINION
CENTRE
Concourse
Run 10 " dia. takeoff
to Standard Life for 225 Ft.
P1
10 " dia. take off for
Tower 3
P2
66 '
140 '


New Buildig on Bay St.
King Street
Bay Street
COMMERCE COURT
P1
Concourse
24 "dia.
24 " dia.
TD1
10 " dia. run 300 ' to Montreal Trust & Dominion Bank
P2
8 " dia. takeoff to New Building
24 "dia.
B2
14 " dia. to TD5
24 "dia.
30 "dia.
2 take off @ 16 " dia. to Commerce Court
P1
P2
P3
170 '
150 '
66'
135 '
200 '
130 '


Jordan St.
Yonge St.
48
Yonge
St.
Valve Chambers
8 " dia.
riser to feed
48 Yonge St.
50 Yonge St.
60 Yonge St.
10 " dia.
run 300 ' to
ontreal Trust &
ominion Bank
18" dia.
30 " dia.
36 " dia.
36 " dia.
Subway Line
39 '
125 '
65 '



Scott St.
8 " dia.
14 " dia.
take off to
King St. E.
6 " dia.
take off to
Wellington St. E.
6 " dia.
take off
6 " dia.
take off
26
Wellington
St. E.
30
Wellington
St. E.
P2
P2
230 '
57 ' 6 "
115 '

Figure 13a
Location of Valve Chamber at Yonge and Wellington Sts.

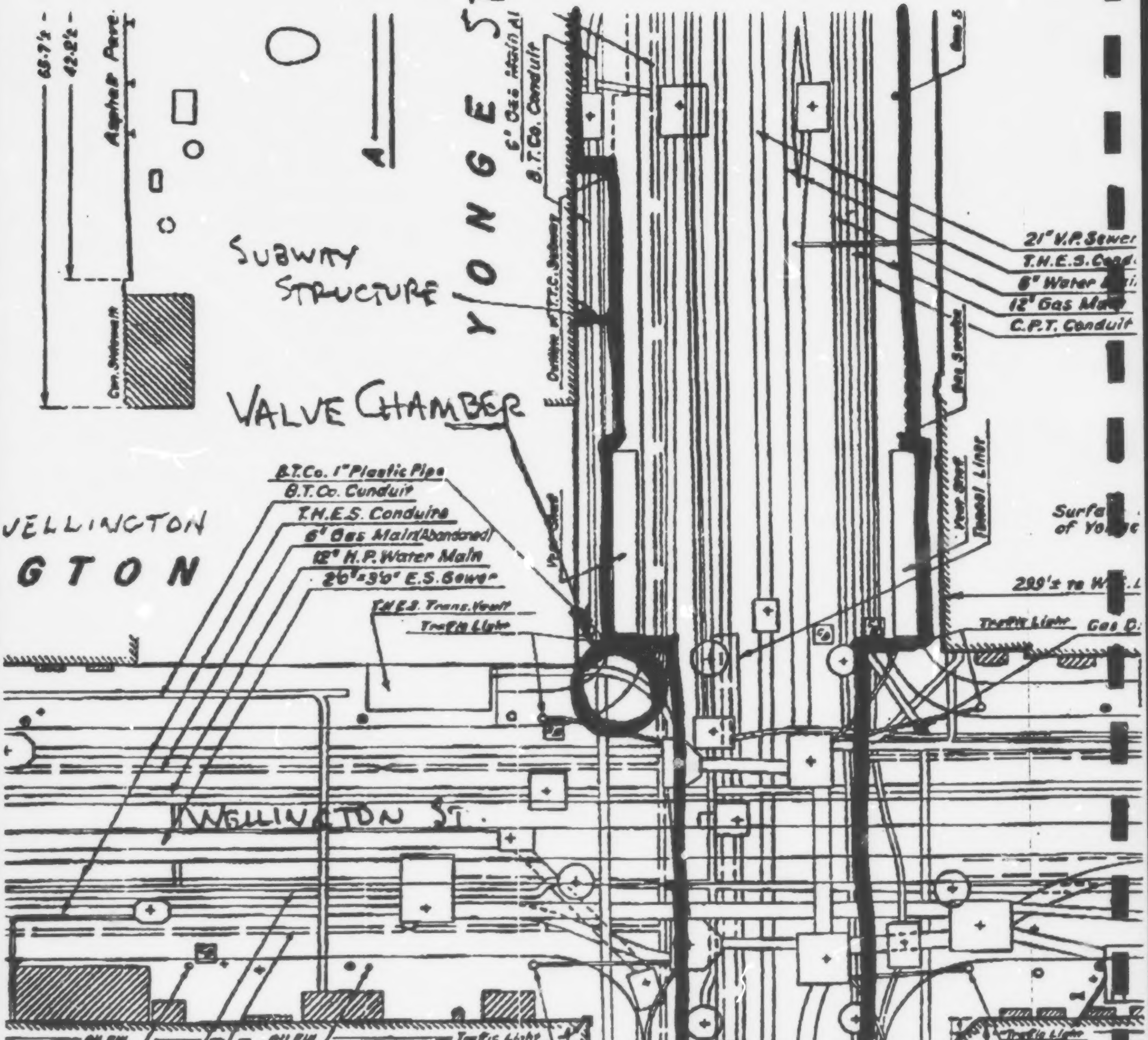

YONGE ST.
SUBWAY STRUCTURE
VALVE CHAMBER
WELLINGTON ST.
VELLINGTON
GTON
65'-7½"
42'-2½"
Asphalt Pave.
Con. Sidewalk
6" Gas Main Al
B.T.Co. Conduit
Outline of T.T.C. Subway
21" V.P. Sewer
T.H.E.S. Cond.
6" Water Mai
12" Gas Main
C.P.T. Conduit
Gas Service
Gas S
Vent Shaft
Tunnel Liner
Surface of Yonge
299's to W.S.L.
Traffic Light
Gas D
B.T.Co. 1" Plastic Pipe
B.T.Co. Conduit
T.H.E.S. Conduits
6" Gas Main (Abandoned)
12" H.P. Water Main
20"×3'0" E.S. Sewer
T.H.E.S. Trans. Vault
Traffic Light
GH PW
GH PW
Traffic Light
12" Water Main
(Abandoned) 6" Gas Main
304's to N.S.L. Front St.
B.T.Co.
T.H.E.S.
Water
Sewer
T.H.E.S.
Water
Gas
C.P.T.
Gas
Traffic Light
274's to N.S.L.

Figure 13b
Location of Valve
Chamber at University Ave
and Wellington St

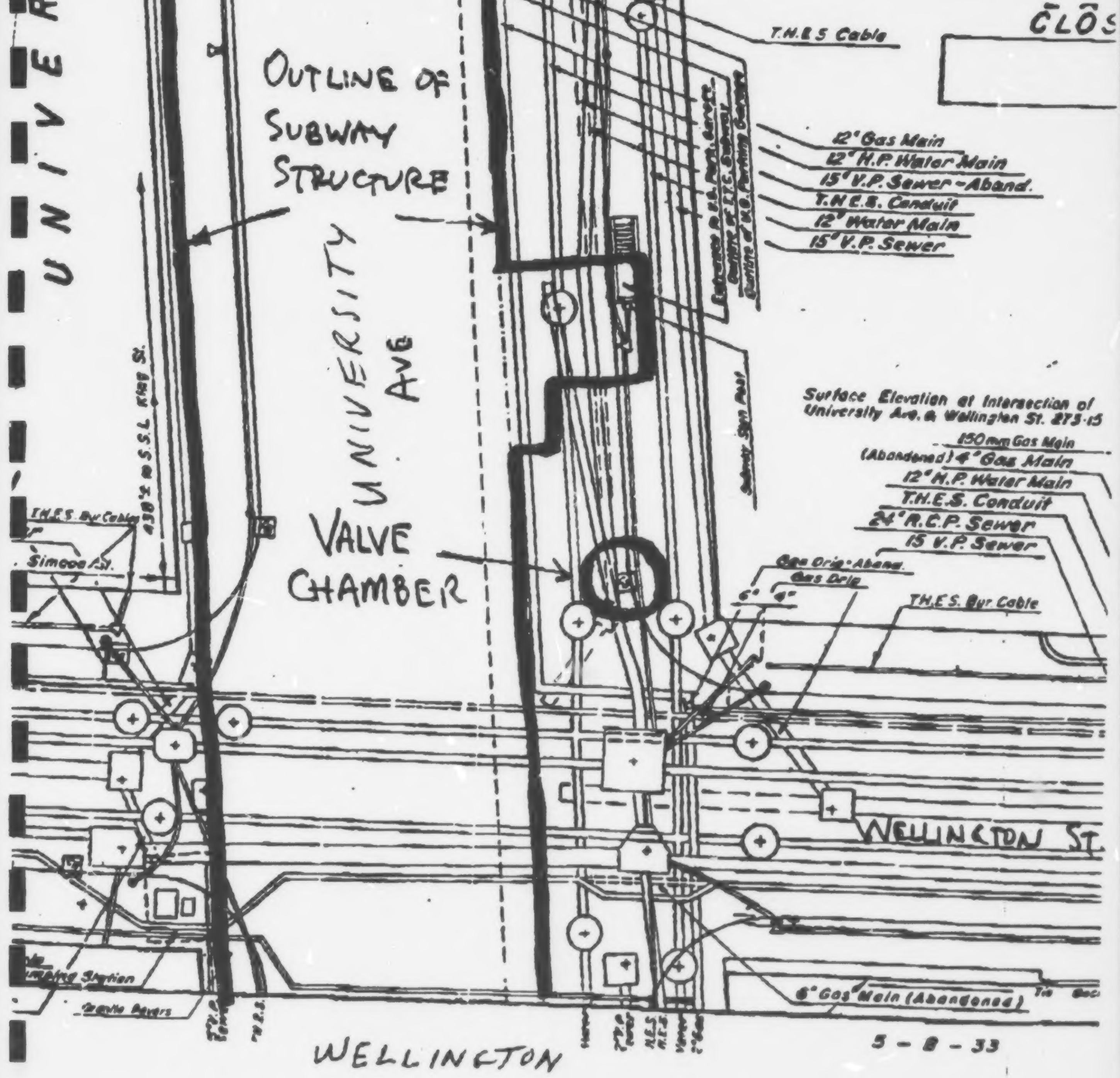
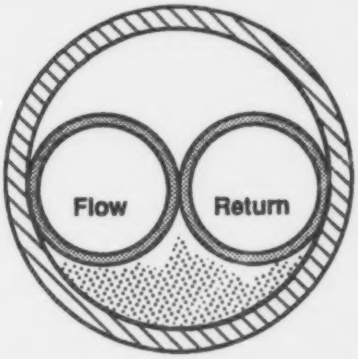

UNIVER
OUTLINE OF SUBWAY STRUCTURE
UNIVERSITY AVE
VALVE CHAMBER
WELLINGTON
WELLINGTON ST.
CLOS
T.H.E.S Cable
Entrance to U.G. Parking Garage
Outline of T.T.C. Subway
Outline of U.G. Parking Garage
12" Gas Main
12" H.P. Water Main
15" V.P. Sewer - Aband.
T.H.E.S. Conduit
12" Water Main
15" V.P. Sewer
Subway Sign Post
Surface Elevation at Intersection of University Ave. & Wellington St. 273.15
150mm Gas Main
(Abandoned) 4" Gas Main
12" H.P. Water Main
T.H.E.S. Conduit
24" R.C.P. Sewer
15 V.P. Sewer
Gas Orig - Aband.
Gas Orig
6"
4"
T.H.E.S. Bur Cable
T.H.E.S. Bur Cable
Simcoe St.
438'± to S.S.L King St.
Pumping Station
Granite Pavers
6" Gas Main (Abandoned)
5 - 8 - 33

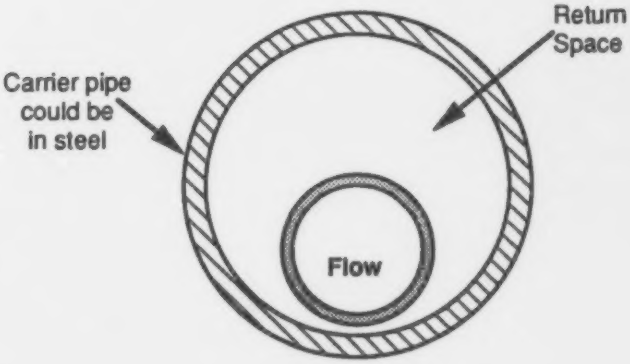
Figure 14

Alternative Micro Tunnelling Concept

Alternative A - Carrier Pipe


Flow
Return

Alternative B - Pipe Within A Pipe


Return Space
Carrier pipe could be in steel
Flow

Alternative C - Direct Bury Installation

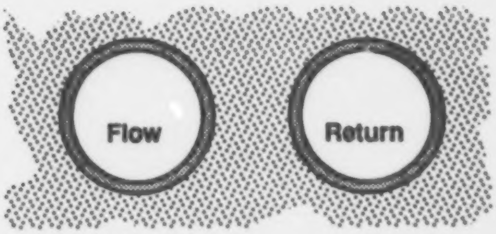

Flow
Return

Figure 13

Plan of King Wellington Branch Line with Micro Tunnelled Headers

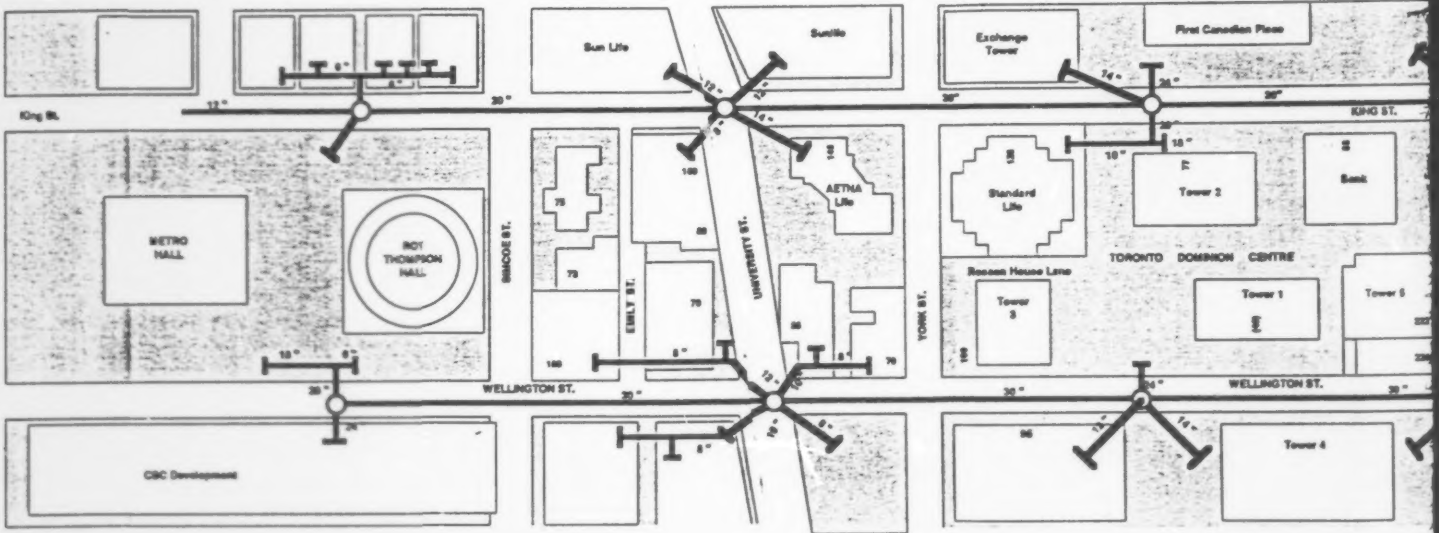

King St.
12"
30"
6"
Sun Life
12"
14"
Sunlife
Exchange Tower
First Canadian Place
14"
24"
30"
KING ST.
18"
10"
Bank
METRO HALL
ROY THOMPSON HALL
SIMCOE ST.
75
73
100
EMILY ST.
100
80
70
UNIVERSITY ST.
145
AETNA Life
96
70
Standard Life
Tower 2
TORONTO DOMINION CENTRE
Rossen House Lane
YORK ST.
Tower 3
100
Tower 1
Tower 5
10"
30"
24"
WELLINGTON ST.
30"
CBC Development
Tower 4

Figure 13

llington Branch Line with Micro Tunnelled Headers

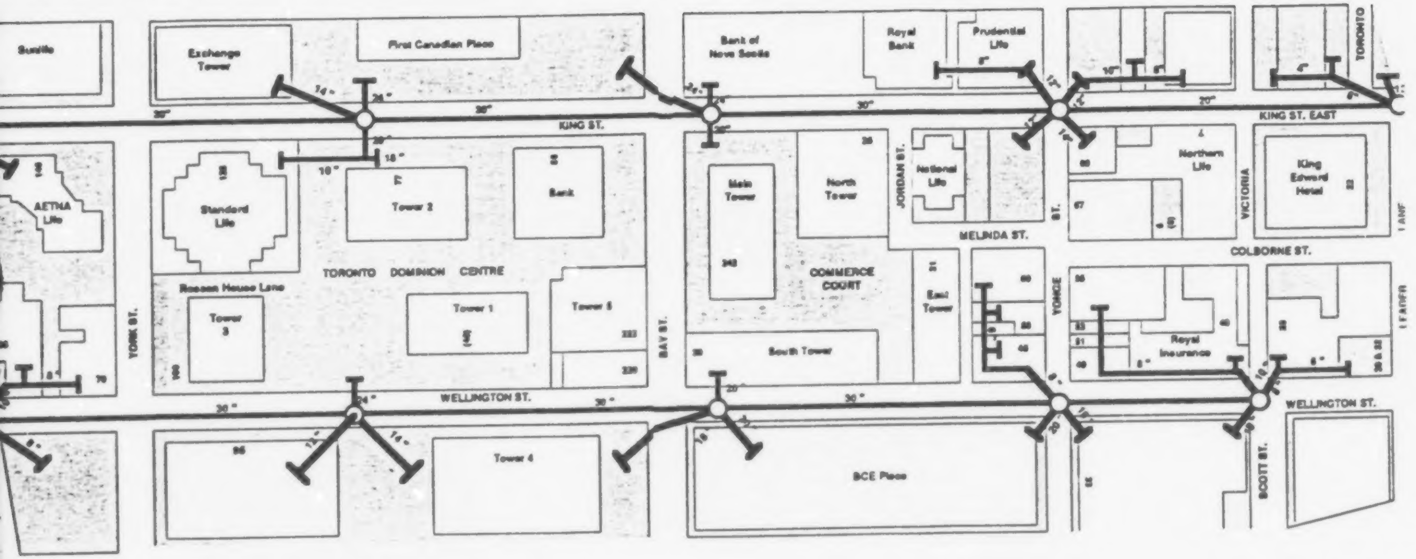

Sunlife
Exchange Tower
First Canadian Place
Bank of Nova Scotia
Royal Bank
Prudential Life
TORONTO
KING ST.
KING ST. EAST
30"
20"
24"
14"
18"
10"
8"
12"
6"
AETNA Life
Standard Life
Tower 2
Bank
TORONTO DOMINION CENTRE
Rosson House Lane
Tower 3
Tower 1
Tower 5
YORK ST.
BAY ST.
Main Tower
North Tower
COMMERCE COURT
South Tower
East Tower
JORDAN ST.
National Life
MELINDA ST.
YONGE ST.
Northern Life
VICTORIA
King Edward Hotel
LANE
COLBORNE ST.
LEADER
Royal Insurance
WELLINGTON ST.
Tower 4
BCE Place
SCOTT ST.
70
95
222
220
20
25
248
67
60
33
31
40
30 & 32

FIGURE 15

BUILDING CONNECTIONS

PIPE SIZE	$/Metre (Supply & Return)	No Connections	Length m	$
24"	930	5	150	139,500
20"	790	13	400	316,000
14"	555	31	950	527,250
10"	400	72	2200	880,000
8"	300	167	5100	1,530,000
6"	250	243	7420	1,855,000
4"	200	70	2140	428,000
TOTAL		601		5,675,750

FIGURE 16

HEADER COST

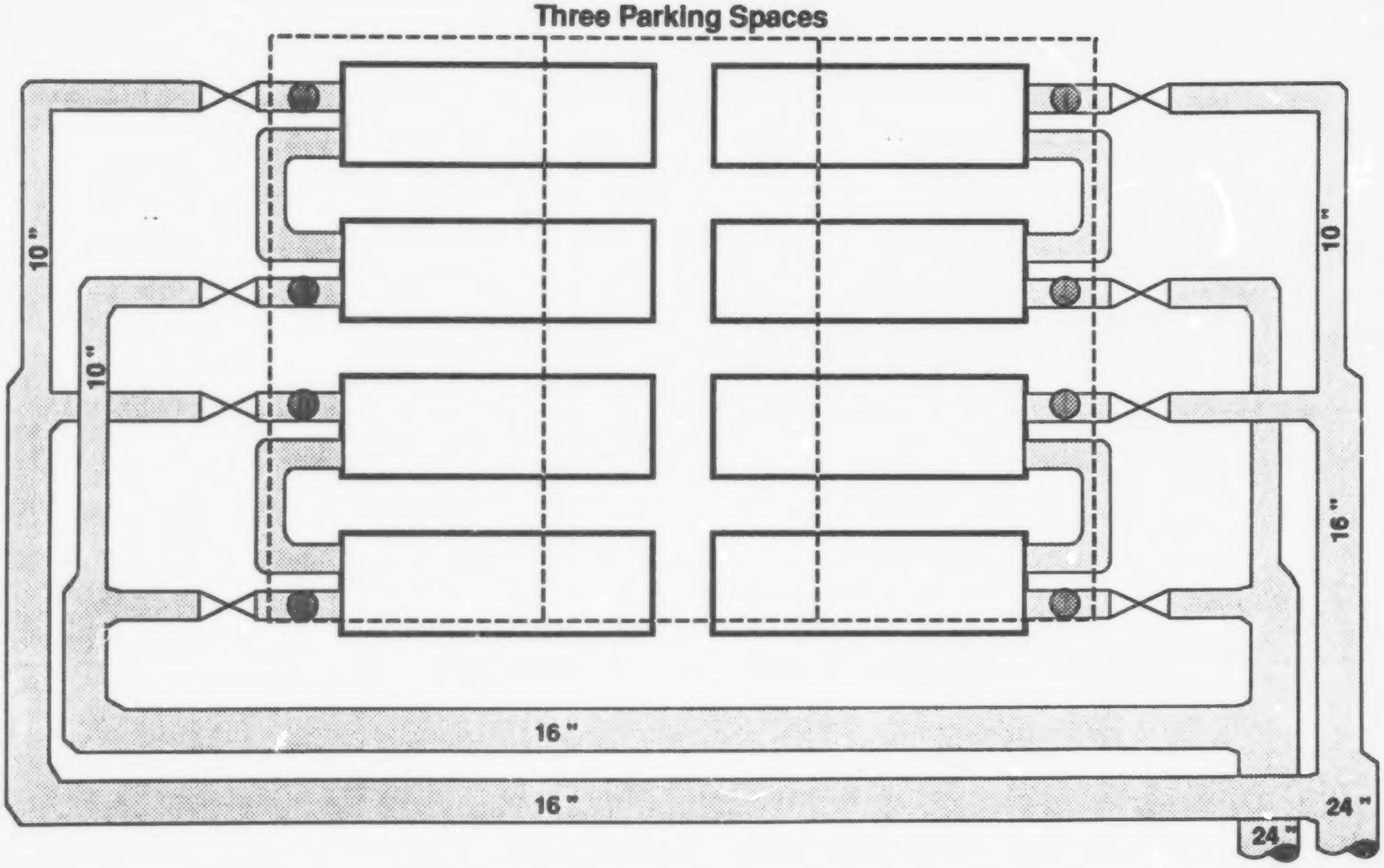
(Insulated Supply pipe plus non-insulated return pipe)

Pipe Size	Length m	COST - 1000$					
		METHOD A		METHOD B		METHOD C	
		$/m	1000$	$/m	1000$	$/m	1000$
36"	764	3888	2,970	3033	2,317	2148	1,641
24"	9721	2728	26,519	2128	20,686	1507	14,650
20"	5853	2360	13,813	1841	10,775	1304	7,632
18"	1323	2195	2,904	1745	2,309	1140	1,508
16"	2210	2112	4,668	1679	3,711	1097	2,424
14"	260	1988	517	1607	418	958	249
12"	4640	1826	8,473	1476	6,849	880	4,083
TOTALS			59,864		47,065		32,187
Add Bldg. conns.			5,676		5,676		5,676
Allowance for Bldg. runnouts			5,000		5,000		5,000
GRAND TOTAL			70,540		57,741		42,863

Figure 17

Floor Plan for Heat Exchangers for a 6000 Ton System

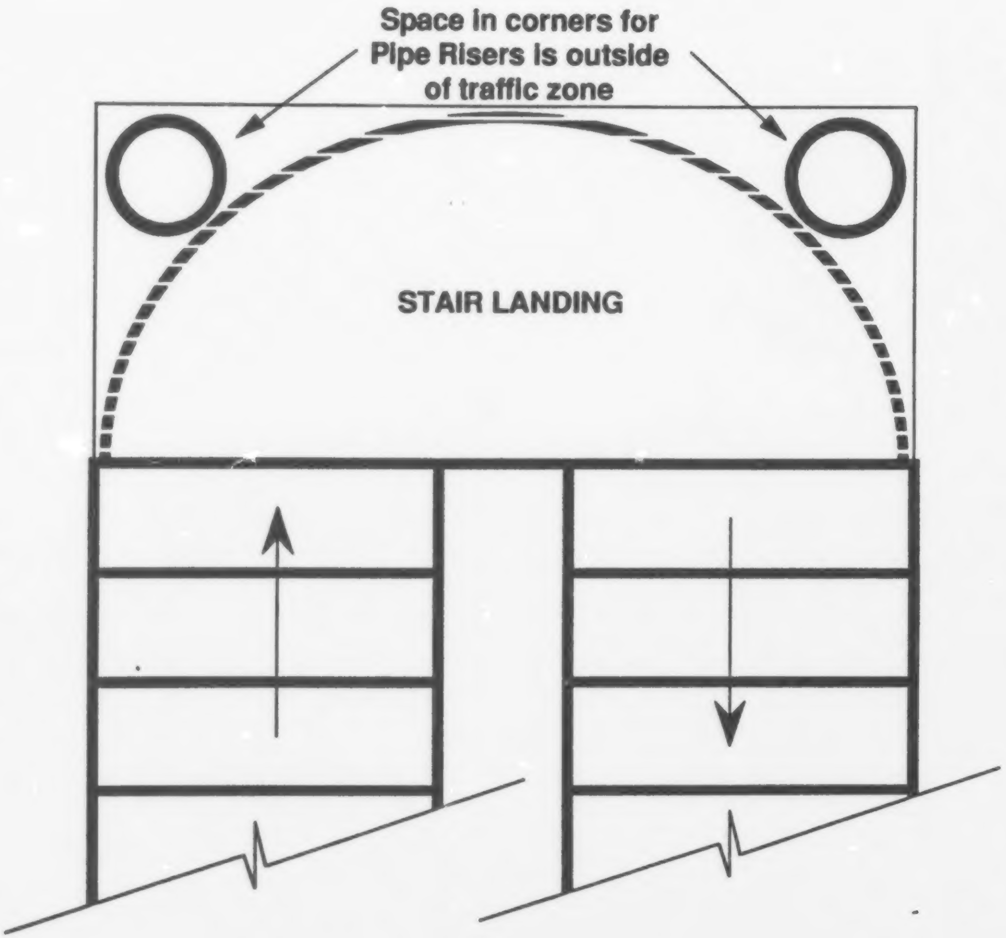
(Piping for Building not Shown)


Three Parking Spaces
10"
10"
10"
16"
16"
16"
24"
24"

BUILDING INFORMATION									CALCULATION OF EQUIV. FULL LOAD HOURS				CHILLED PLANT SERVICING COSTS, $/yr.				ESTIMATE OF CUSTOMER'S CONNECTION COST							ASSUME: PIPES IN BASEMENT?
				Cooling Cap., tons						Given Operating Time				Given Information					Cost of Lines					
Address	Common Name	Area, sq. ft.	No of Flrs.	Orig. Est.	Conf. Cap.	Chiller Location	Age, yr & (no.)	System Type	Orig. Est.	hrs/day	mnths/yr	Revised Est.	Original Estimate	Serv Cont Lab crt	Hot Water HR-up Cost	Total	Line Size, in.	Line Length, ft.	MEARS, 1991	Our Estimate	Controls & Inst's	Heat Exchanger	Total	
233 King W.	Metro Hall	650,000	19	3,000	2,100	17th Flr	New (2)	Compart.	1,875	Not yet operating		1,875					14	800	174,048	504,000	50,000	250,000	804,000	
60 Simcoe St.	Roy Thompson Hall	200,000	4	1,000	330	Basement	10 (2)	Central	1,160	16	12	1,875		8,400	2,625	11,025	6	130	17,118	54,000	21,000	44,000	119,000	Yes
100 Wellington W.	Trilea Corp. Ltd.	200,000	18	500	810	19th Flr	20 (2)	Central	1,160			1,160		26,000	2,366	28,366	8	350	51,240	168,000	30,000	63,000	261,000	Yes
73 Simcoe St.	St. Andrews Square	160,000	16	150	160	17th Flr	1 (1)	Fan/coil	1,875			1,875		NA	NA	NA								
70 University Av.	Hammerson	200,000	14	300	400	13th Flr	6 (2)	Central	1,160			1,160		26,000	1,656	27,656	6	300	34,236	108,000	25,000	50,000	183,000	Pending
90 University Av.	Ensof Fibreglas	100,000	13	250	200	14th Flr	34 (1)	Central	1,160	16	7	1,180		25,680	3,062	28,742	8	425	62,220	204,000	40,000	83,000	327,000	Pending
100 University Av.	Ensof Fibreglas	140,000	13	350	400	14th Flr	34 (1)	Central	1,160	16	7	1,160												
55 University Av.	Bramalea Prop.	270,000	18	675	900	19th Flr	1 (2)	Central	1,160	11	5.5	900		21,000	2,560	23,560	10	400	72,640	240,000	40,000	100,000	380,000	Yes
70 York St.	Hong Kong Bank	200,000	17	500	700	18th Flr	New (2)	Central	1,160	Not yet operating		1,160		31,000	3,248	34,248	8	350	51,240	168,000	30,000	88,000	286,000	Pending
145 King W.	Aetna Life/York Ctr.	700,000	35	4,750	3,000	14th Flr	20 (2)	Central	1,160	20	8	1,800		64,300	14,400	78,900	14	375	108,780	315,000	50,000	250,000	615,000	Yes
121 King W.	Standard Life	580,000	33	1,350	1,200	23rd Flr	18 (2)	Compart.	1,375	13	12	1,375		25,400	6,600	32,000	8	500	73,200	240,000	40,000	150,000	430,000	Yes
100 Wellington W.	TD Centre, Tower 3	830,000	38	1,400	2,000	31st Flr	18 (2)	Central	1,160	13	8	1,160		138,000	65,856	203,856	14	300	87,024	252,000	50,000	250,000	552,000	Pending
77 King W.	TD Centre, Tower 2	940,000	44	2,500	4,000	45th Flr	24 (3)	Central	1,160	13	8	1,160					18	300	124,082	324,000	75,000	500,000	899,000	•
66 Wellington W.	TD Centre, Tower 1	1,300,000	56	3,500	6,000	56th Flr	28 (4)	Central	1,160	13	8	1,160					24	400	221,568	576,000	100,000	750,000	1,426,000	•
55 King W.	TD Bank	60,000	1	150	150			Central	1,160	10	8	1,160												•
222 Bay St.	TD Centre, Tower 5	650,000	33	1,600	2,000	36th Flr	New (2)	Central	1,160	13	8	1,160					14	550	159,344	462,000	40,000	250,000	752,000	•
220 Bay St.	New Building	230,000	13	600	600	13th Flr		Compart.	1,875	Not yet operating		1,160												
TD Centre Underground		500,000	1	Incl. above						16	12	2,000												•
243 Bay St.	Commerce Court West	1,250,000	57	4,000										130,000	90,428	220,428	16	750	250,800	720,000	65,000	375,000	1,160,000	Pending
25 Wellington W.	Commerce Court East	166,000	14	400	2,905	42nd Flr	20 (2)	Central	1,160	13	8	1,160												•
	Concourse	130,000	1	1,000																				
	Electronic Services	150,000	1		1,920	Basmt 2	20 (2)	Central	8,760	24	12	8,760					10	400	72,640	240,000	40,000	130,000	400,000	•
25 King W.	Commerce Court North	215,000	33	550	1,042	Basement	26 (2)	Central	1,160	13	8	1,160					10	150	27,240	90,000	40,000	120,000	250,000	•
30 Wellington W.	Commerce Court South	100,000	8	210	1,782	Basmt 2	20 (2)	Central	1,160	13	8	1,160					10	150	27,240	90,000	40,000	120,000	250,000	•
11 King W.	Montreal Trust	225,000	19	550	370	20th Flr	26 (2)	Central	1,160	10	7.5	1,160		36,500	1,717	38,217	8	400	43,648	144,000	25,000	45,000	214,000	Yes
5 King W.	New Building	160,000	48	200	200			Fan/coil	1,875	Not yet operating		1,875												
1 King W.	TD Bank	200,000	11	300	300	Basement	2 (1)	Central	1,160	12	5.5	820		13,000	984	13,984	8	150	17,118	54,000	25,000	38,000	117,000	Yes
60 Yonge St.	Norwich Union	85,000	11	150	250	12th Flr	34 (1)	Central	1,160	12	5	800		9,300	800	10,100	6	230	28,330	90,000	25,000	32,000	147,000	Yes
56 Yonge St.	Hotel Victoria	40,000	8	100	100			Package	1,875			1,875												Yes
40 Yonge St.	Yonge-Wellington Prop	100,000	12	250	200	Basement	22 (1)	Central	1,160	12	5	800		12,000	1,248	13,248	6	70	7,988	25,200	15,000	48,000	89,200	Yes
55 Yonge St.	H & R Properties	160,000	14	400	400	13th Flr	28 (1)	Central	1,160	12	5	820					6	300	34,236	108,000	25,000	50,000	183,000	Yes
15 Wellington E.	Royal Insurance Grp.	120,000	7	275	600	8th Flr	13 (2)	Central	1,160	24	7.5	1,200		33,300	3,060	36,360	8	290	36,800	120,000	35,000	75,000	230,000	Pending
25 Wellington E.	H & R Properties	160,000	13	400	300	14th Flr	8 (2)	Compart.	1,875	12	12	1,875		5,000	2,350	7,350	6	300	34,236	108,000	25,000	38,000	171,000	Yes
30 Wellington E.	Royal Lepage		13					Compart.	1,875	12	12	1,875												Pending
7 King E.	Northern Life	300,000	22	750	1,100	8th Flr	30 (1)	Central	1,160	24	8.5	1,200		11,000	5,280	16,280	10	250	45,400	150,000	40,000	138,000	328,000	Pending
6 Colborne St.		40,000	6	100	100			Package	1,875	10	12	1,200												Yes
87 Yonge St.		75,000	16	175	100			Package	1,875	10	12	1,200		10,000	400	10,400	4	300	21,400	72,000	25,000	15,000	112,000	Yes
69 Yonge St.	H & R Properties	225,000	17	900	250			Package	1,875	10	12	1,200		21,000	1,200	22,200	6	300	34,236	108,000	25,000	40,000	173,000	Yes
	TOTALS	11,482,000		30,125	35,730									647,200	209,628	856,916			1,920,270	5,734,200	1,041,000	4,083,000	10,858,200	

Figure 19

Ideal Location for Pipe Risers


Space in corners for Pipe Risers is outside of traffic zone
STAIR LANDING

FREECOOL PROJECT

PIPING COSTS PER MEANS CATALOGUE

SIZE, in.	COST/ft.	COST/ ft-in	ADD. for HANGERS + 5%	COST for 1" insul c/w COVER /ft-in	TOTAL	x 1.06 .865
4	23.00	5.75		1.53	7.28	8.92
6	39.00	6.50		1.26	7.76	9.51
8	50.00	6.25		1.22	7.47	9.15
10	63.00	6.30		1.11	7.41	9.08
12	77.04	6.42		1.05	7.47	9.15
14	99.96	7.14	7.50	0.96	8.46	10.36
16	115.04	7.19	7.55	0.98	8.53	10.45
18	145.08	8.06	8.46	0.91	9.37	11.49
20	165.00	8.25	8.66	0.93	9.59	11.75
24	195.12	8.13	8.54	0.88	9.42	11.54
30	249.90	8.33	8.75	0.85	9.60	11.76

PIPING COSTS PER CANADIAN CATALOGUE

			1" INSUL/ ft-in	COVER	
4	60.00	15.00	1.83	0.90	17.73
6	100.00	16.67	1.47	0.75	18.88
8	146.00	18.25	1.34	0.61	20.20

FIGURE 20

Figure 21

Piping & Control for Heat Exchangers

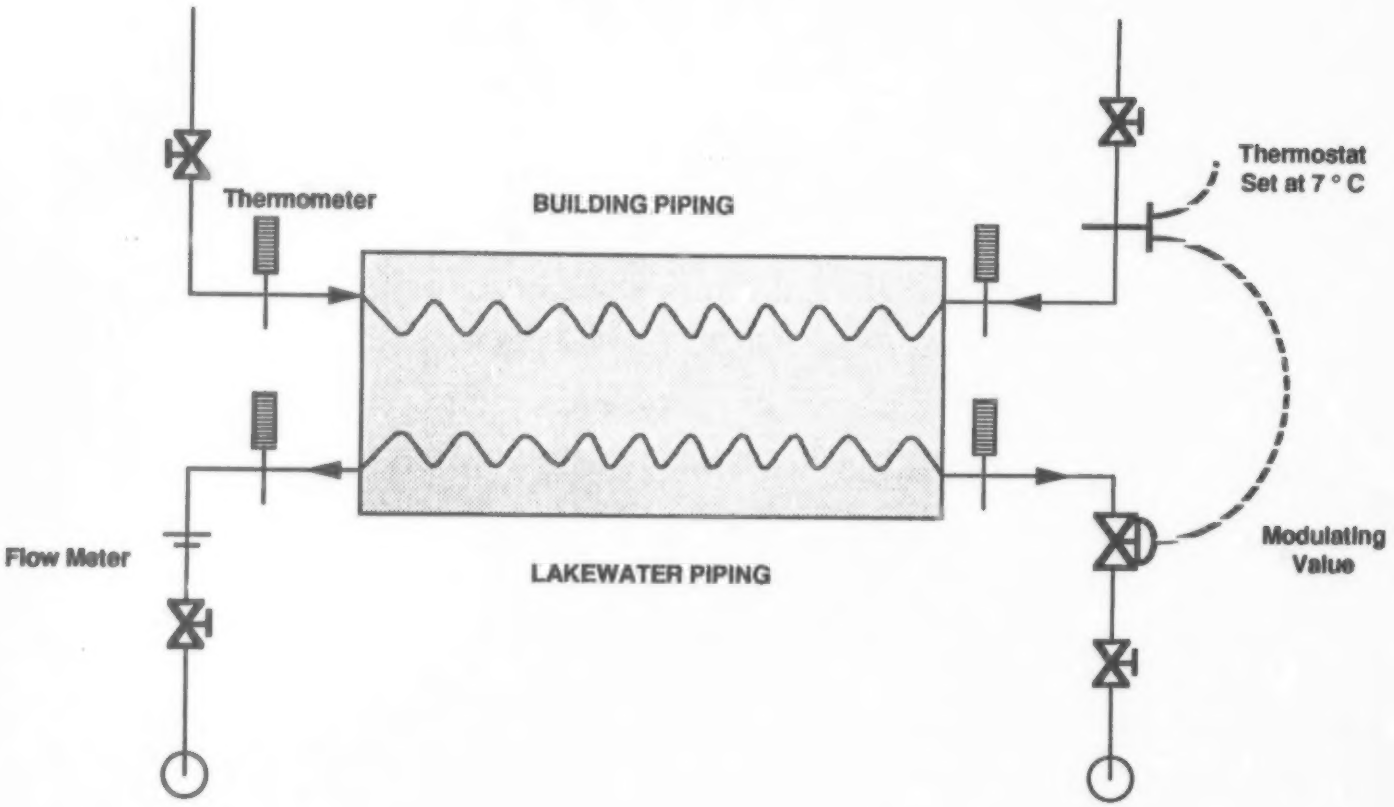

Thermometer
BUILDING PIPING
Thermostat
Set at 7 ° C
Flow Meter
LAKEWATER PIPING
Modulating
Value

Figure 22
Prospective Rate Scale

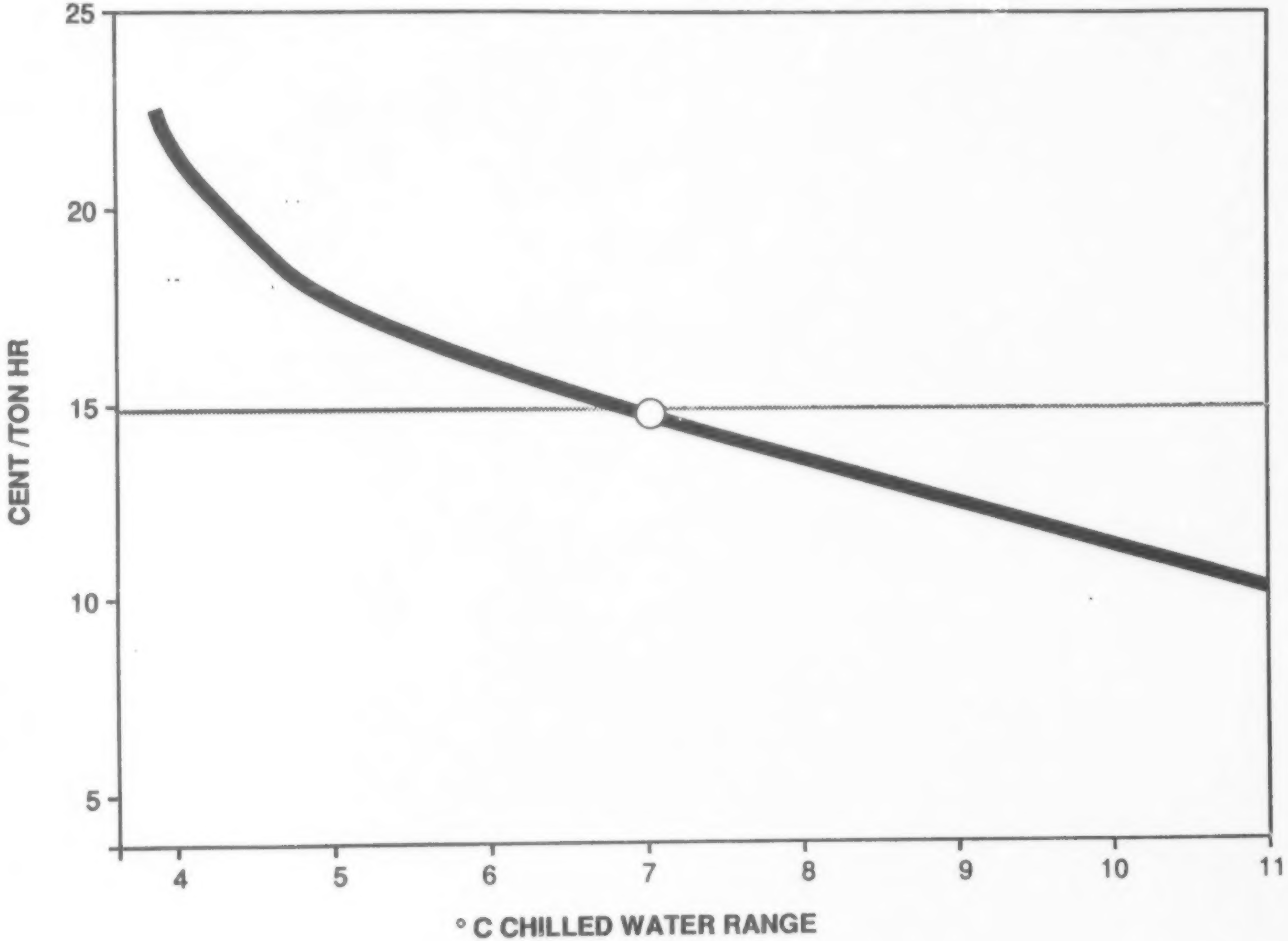


Figure 23

Temperature Isopleths (in ° C) for Toronto Harbour

(May 10 to Oct. 26, 1989)

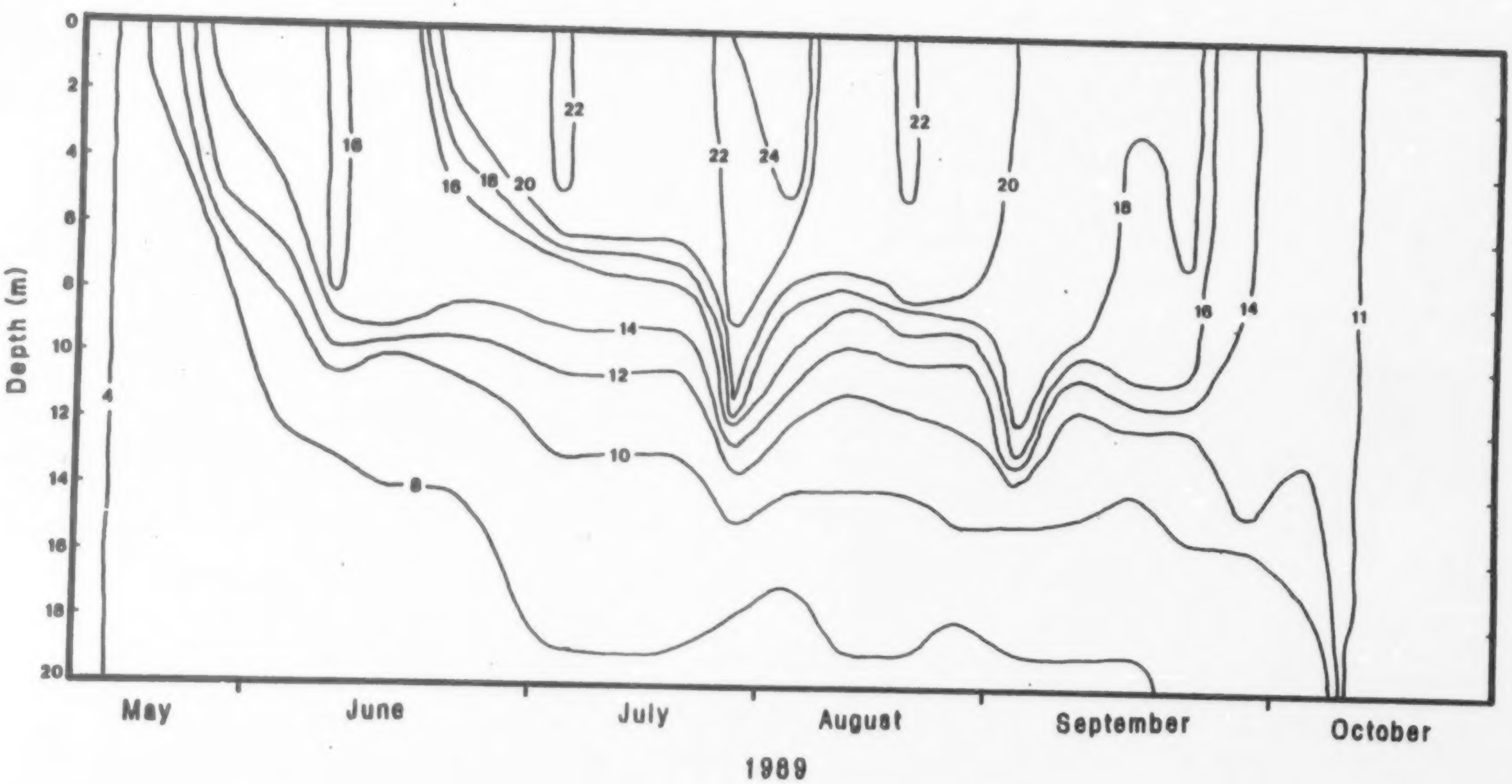


FIGURE 24

SUMMARY OF FLOOR AREA m^2

FOR DOWNTOWN TORONTO COOLING LOADS

CATEGORY	EXISTING	UNDER CONSTRUCTION	CONTEMPLATED	TOTAL AREA	TOTAL %
OFFICES	6,631,000	1,063,000	1,521,000	9,215,000	57%
RESIDENTIAL	1,380,000	285,000	1,862,000	3,527,000	22%
HOSPITALS	531,000	153,000	25,000	709,000	4 1/2%
HOTELS	414,000	113,000	34,000	561,000	3 1/2%
RETAIL	505,000	100,000	200,000	805,000	5%
SCHOOLS (U of T)	920,000	-	-	720,000	4 1/2%
THEATRES incl. ROM Harbourfront	35,000	-	20,000	55,000	1%
CONVENTION CENTRES	110,000	-	-	110,000	1%
JUDICIARY	40,000	-	15,000	55,000	1%
TOTALS **%**	**10,566,000** **66%**	**1,714,000** **11%**	**3,677,000** **23%**	**15,957,000** **100%**	**100%**

FIGURE 25

SUMMARY OF MAJOR DOWNTOWN TORONTO COOLING LOADS

TONS

CATEGORY	EXISTING	UNDER CONSTRUCTION	CONTEMPLATED	TOTAL	%
OFFICES	165,775	26,575	38,025	230,375	67
RESIDENTIAL	13,800	2,850	18,620	35,270	10
HOSPITALS	13,275	3,825	625	17,725	5
HOTELS	10,350	2,825	850	14,025	4
RETAIL	12,625	2,500	5,000	20,125	6
SCHOOLS	18,000	-	-	18,000	5
THEATRES	3,000	-	1,200	4,200	1
CONVENTION EXHIBITION	2,750	-	-	2,750	1
JUDICIARY	1,000	-	375	1,375	1
TOTALS %	240,575 70%	38,575 11%	64,695 19%	343,845 100%	100%

Figure 26

Maximum Outdoor Temperature at 315 Bloor Street West

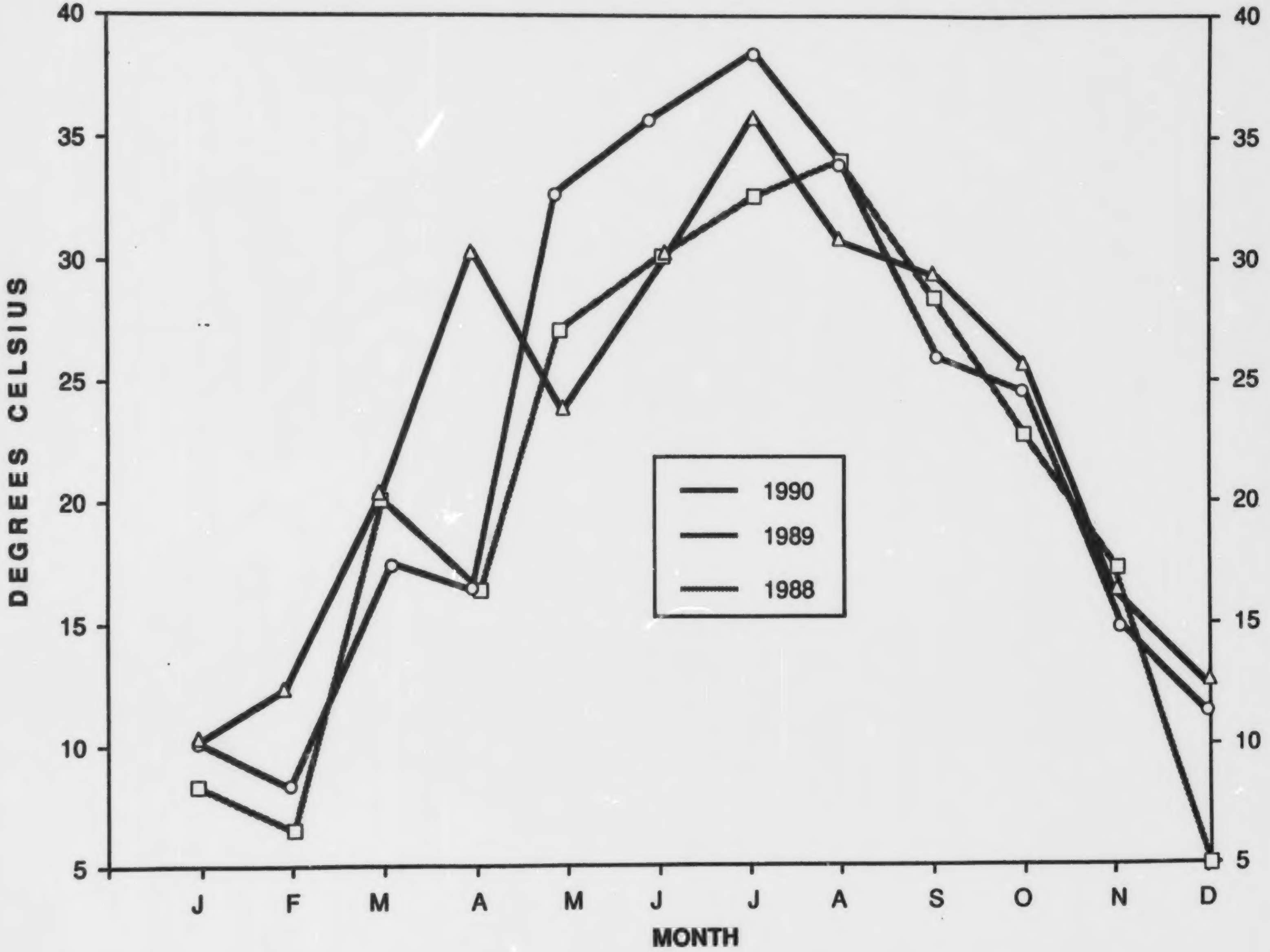


Figure 27

Relationship of Cooling Load to Outdoor Temperature

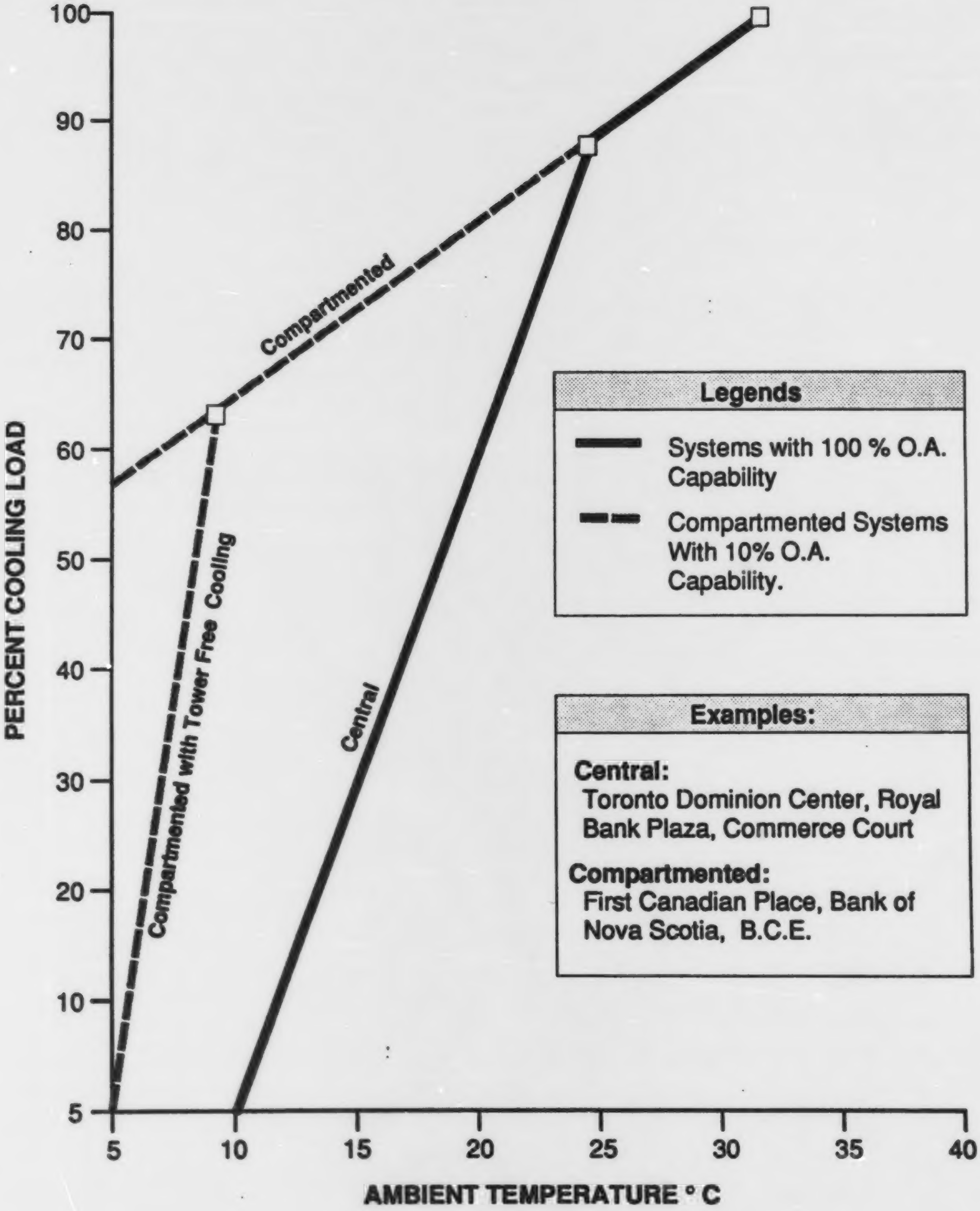
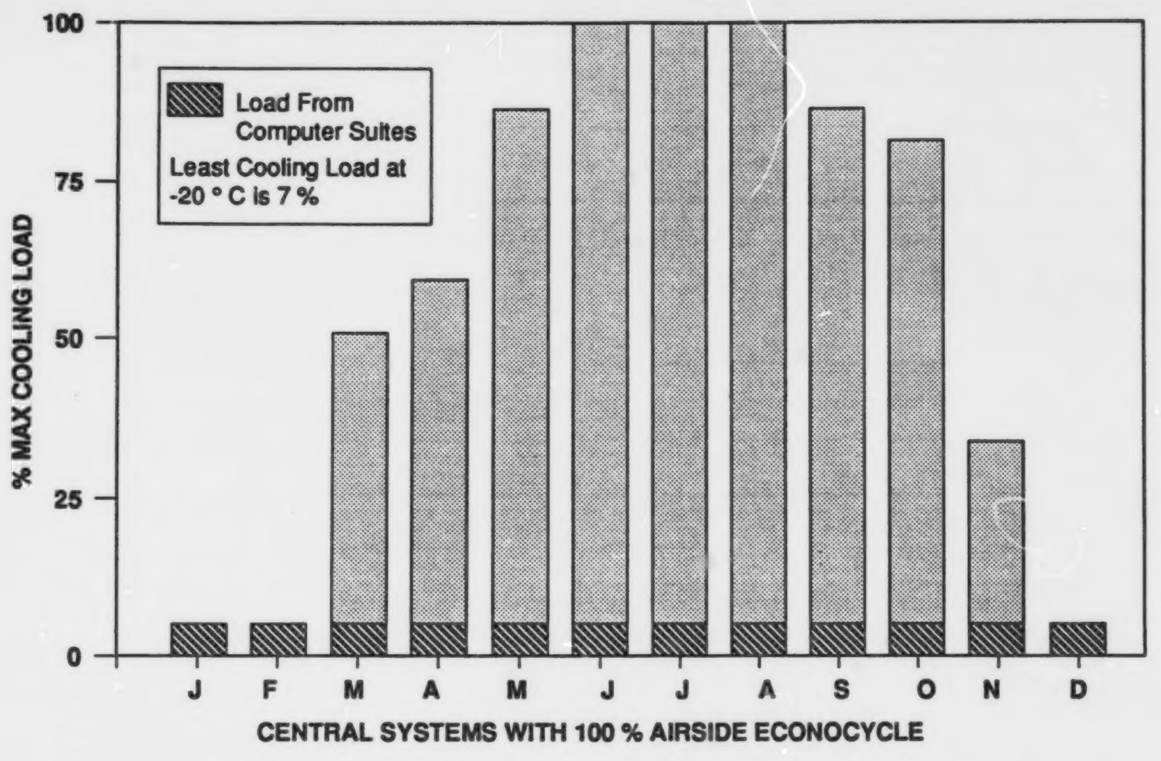


Figure 28

Maximum Month Cooling Loads



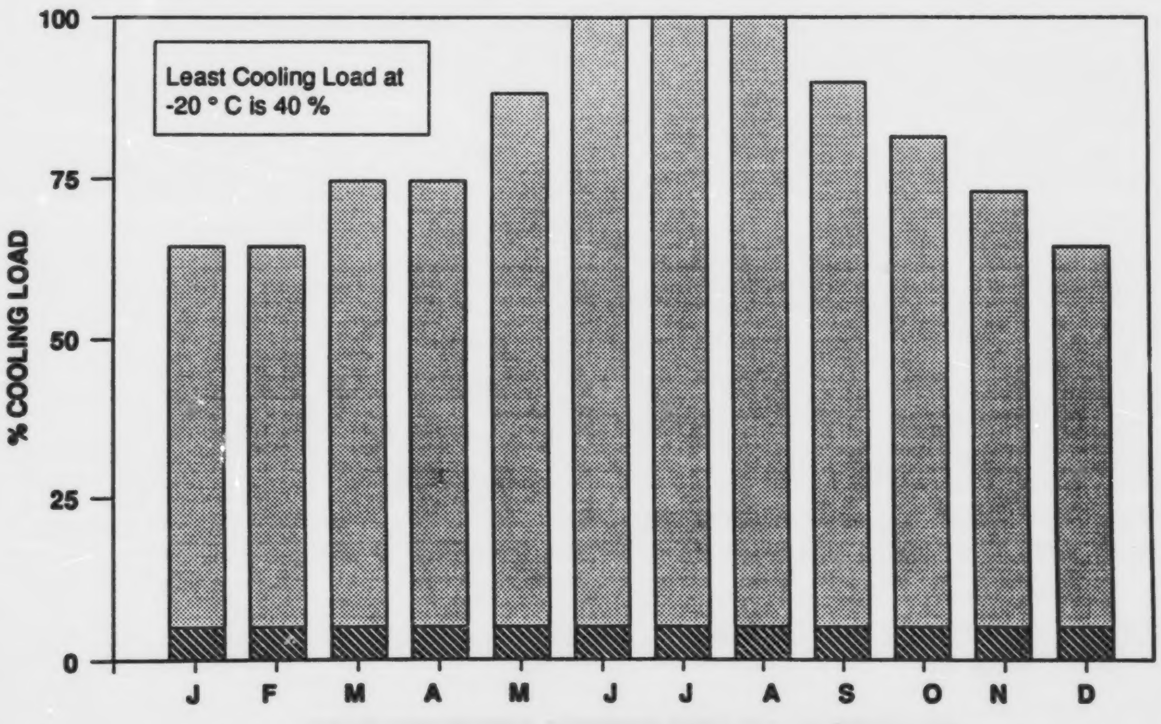


FIG. 29 CHILLER DEMAND COST

NOTE: BASED ON 1991 RATES FOR ORIGINAL SYSTEM CAPACITY OF 200000 TONS

MONTH	MAX. TEMP. C	% FULL LOAD AT MAX. TEMP. CENTRAL	% FULL LOAD AT MAX. TEMP. COMP'T	MAXIMUM MONTHLY LOAD (TONS) CENTRAL	MAXIMUM MONTHLY LOAD (TONS) COMP'T	TOTAL	CHILLER DEMAND (0.75 KW/TON) CENTRAL	CHILLER DEMAND (0.75 KW/TON) COMP'T	TOTAL	ELECTRIC DEMAND COST ($14.36/KW) CENTRAL	ELECTRIC DEMAND COST ($14.36/KW) COMP'T	TOTAL
JAN	10	0	65	0	26000	26000	0	19500	19500	0	280020	2800
FEB	10	0	65	0	26000	26000	0	19500	19500	0	280020	2800
MAR	20	60	81	96000	32400	128400	72000	24300	96300	1033920	348948	13828
APR	25	89	89	142400	35600	178000	106800	26700	133500	1533648	303412	19170
MAY	30	97	97	155200	38800	194000	116400	29100	145500	1671504	417876	20893
JUN	35	100	100	160000	40000	200000	120000	30000	150000	1723200	430800	21540
JUL	35	100	100	160000	40000	200000	120000	30000	150000	1723200	430800	21540
AUG	35	100	100	160000	40000	200000	120000	30000	150000	1723200	430800	21540
SEP	27	92	92	147200	36800	184000	110400	27600	138000	1585344	396336	19816
OCT	25	89	89	142400	35600	178000	106800	26700	133500	1533648	383412	19170
NOV	17	42	76	67200	30400	97600	50400	22800	73200	723744	327408	10511
DEC	10	0	65	0	26000	26000	0	19500	19500	0	280020	2800
TOTALS				1230400	407600	1638000	922800	305700	1228500	13251408	4389852	176412

FIGURE 29

FIG. 30 CHILLER ENERGY COST

NOTE: BASED ON 1991 RATES FOR ORIGINAL SYSTEM CAPACITY OF 200000 TONS

	EQUIVALENT FULL LOAD HOURS		MEGAWATT HOURS FLHx.75 KW/TON x MAX. TONS			NET ENERGY COST-$ ($.0395/KWH)		
MONTH	CENTRAL	COMP'T	CENTRAL	COMP'T	TOTAL	CENTRAL	COMP'T	TOTA
JAN	0	100	0	3000	3000	0	118500	11850
FEB	0	100	0	3000	3000	0	118500	1185[illegible]
MAR	25	125	3000	3750	6750	118500	148125	-266[illegible]
APR	75	150	9000	4500	13500	355500	177750	53325
MAY	125	175	15000	5250	20250	592500	207375	7998[illegible]
JUN	175	200	21000	6000	27000	829500	237000	10665[illegible]
JUL	225	250	27000	7500	34500	1066500	296250	13627
AUG	200	225	24000	6750	30750	948000	266625	121462
SEP	160	175	19200	5250	24450	758400	207375	965[illegible]
OCT	125	150	15000	4500	19500	592500	177750	770[illegible]
NOV	50	125	6000	3750	9750	237000	148125	38512
DEC	0	100	0	3000	3000	0	118500	1185[illegible]
TOTALS	1160	1875	139200	56250	195450	5498400	2221875	772027

FIGURE 30

FIG.31 ELECTRIC DEMAND FOR TOWER FAN AND PUMPS

	% FULL LOAD AT MAX. MONTHLY TEMP		MAX. MONTHLY LOAD (TONS)		MAX. ELEC. DEMAND (.25 KW/TON)		COST ($14.36/KW)		
MONTH	CENTRAL	COMP'T	CENTRAL	COMP'T	CENTRAL	COMP'T	CENTRAL	COMP'T	TOTAL
JAN	0	85	0	34000	0	8500	0	122060	122060
FEB	0	85	0	34000	0	8500	0	122060	122060
MAR	80	90	128000	36000	32000	9000	459520	129240	588760
APR	95	95	152000	38000	38000	9500	545680	136420	682100
MAY	100	100	160000	40000	40000	10000	574400	143600	718000
JUN	100	100	160000	40000	40000	10000	574400	143600	718000
JUL	100	100	160000	40000	40000	10000	574400	143600	718000
AUG	100	100	160000	40000	40000	10000	574400	143600	718000
SEP	95	95	152000	38000	38000	9500	545680	136420	682100
OCT	95	95	152000	38000	38000	9500	545680	136420	682100
NOV	65	90	104000	36000	26000	9000	373360	129240	502600
DEC	0	85	0	34000	0	8500	0	122060	122060
			1328000	448000	332000	112000	4767520	1608320	6375840

FIGURE 31

FIG.32 . TOWER ENERGY COST

	EQUIVALENT FULL LOAD HOURS DEMAND		MEGAWATT HOURS		ENERGY COST AT $.0395/KWH		
			CENTRAL	COMP'T			
MONTH	CENTRAL	COMP'T	(40/FLH)	(10/FLH)	CENTRAL	COMP'T	TOTAL
JAN	0	200	0	2000	0	79000	79000
FEB	0	200	0	2000	0	79000	79000
MAR	50	200	2000	2000	79000	79000	158000
APR	125	250	5000	2500	197500	98750	296250
MAY	250	300	10000	3000	395000	118500	513500
JUN	350	400	14000	4000	553000	158000	711000
JUL	450	450	18000	4500	711000	177750	888750
AUG	425	425	17000	4250	671500	167875	839375
SEP	375	375	15000	3750	592500	148125	740625
OCT	250	300	10000	3000	395000	118500	513500
NOV	150	200	6000	2000	237000	79000	316000
DEC	0	200	0	2000	0	79000	79000
	2425	3500	97000	35000	3831500	1382500	5214000

FIGURE 32

Figure 33

TORONTO HYDRO MAXIMUM DAILY LOAD PROFILE

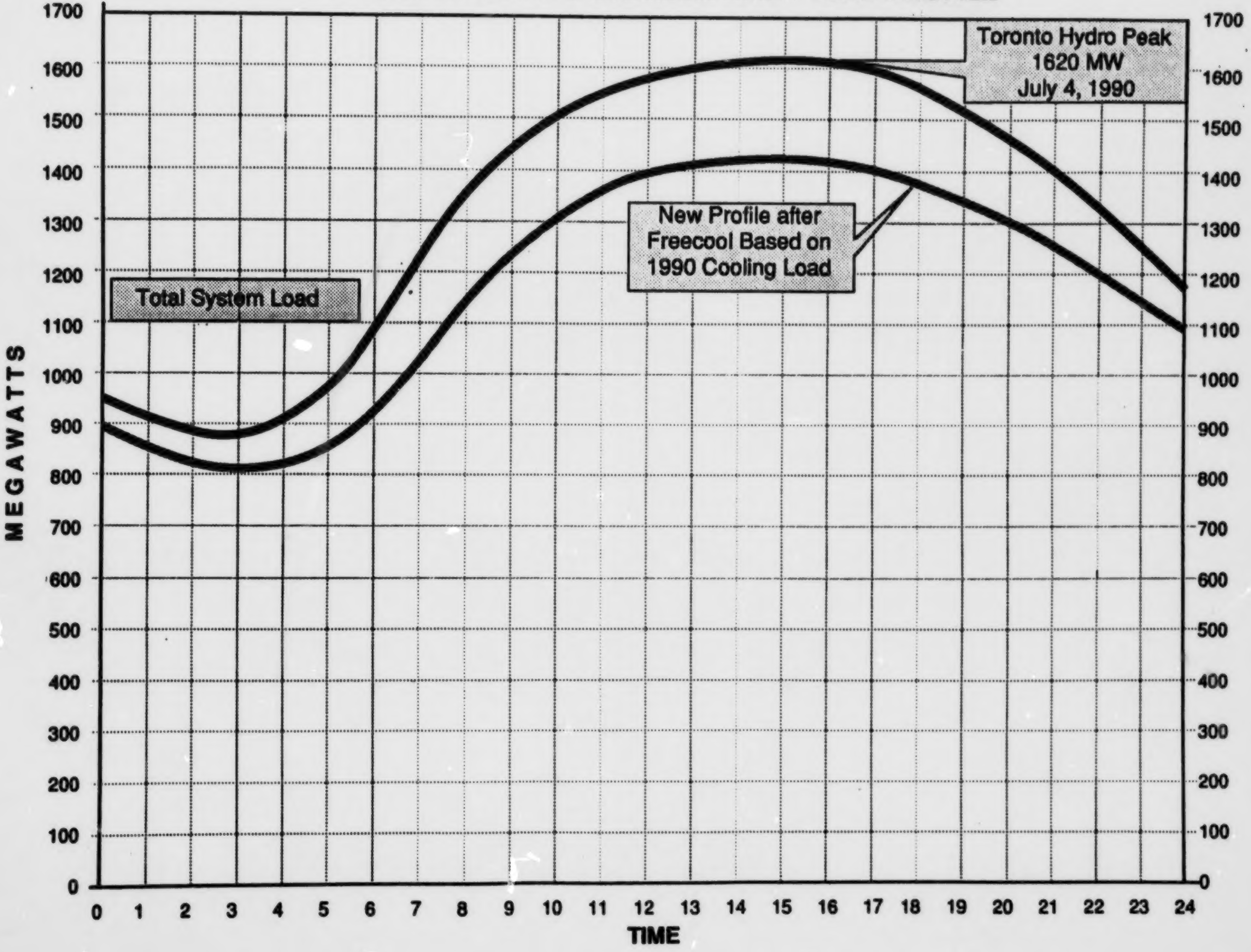


Figure 34

Graph to Show Average Relationship of Water Tower Energy to Cooling Load for a Mix of Large & Small Cooling Plants

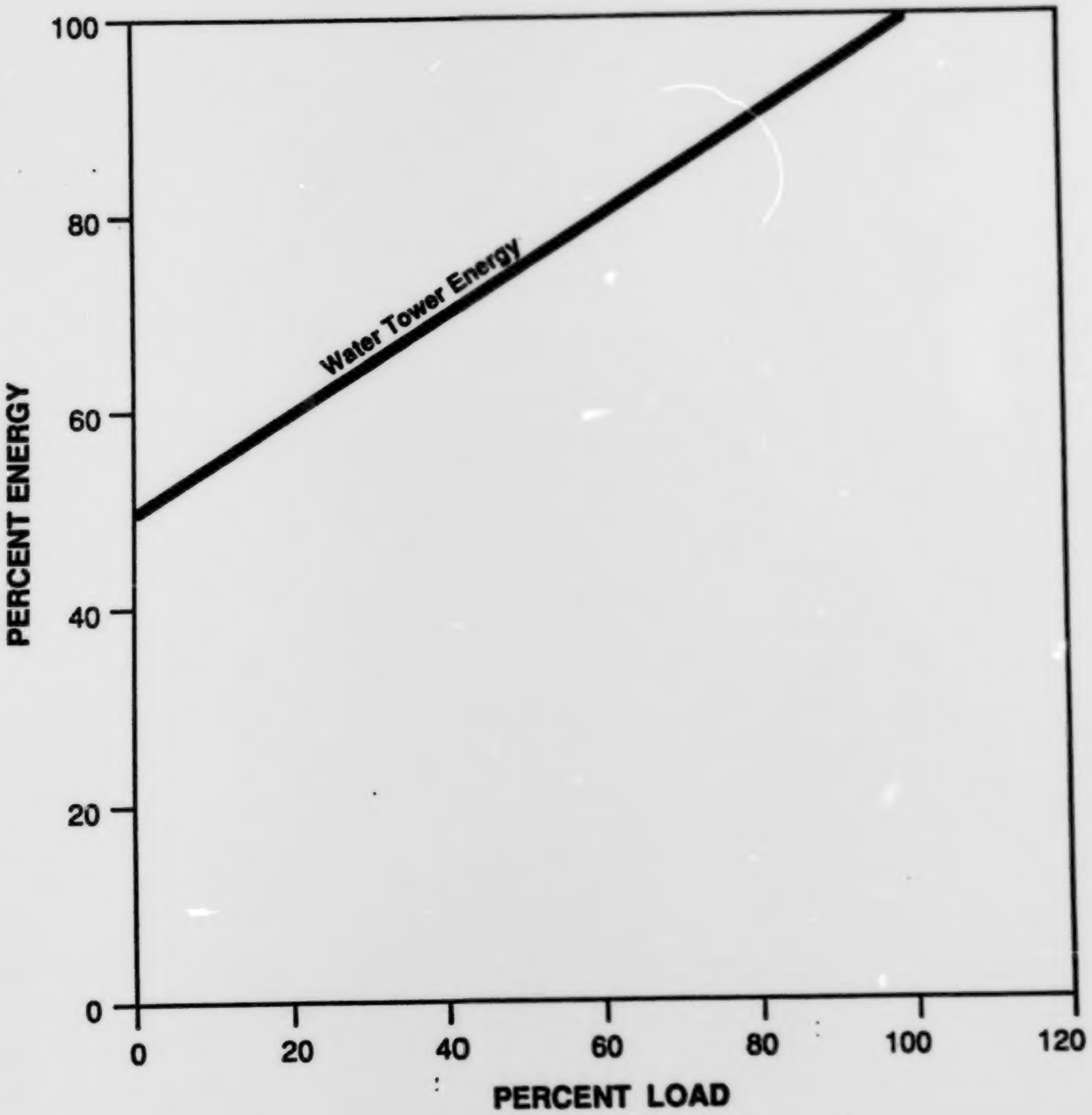


FIG. #35 ON-SITE COSTS PER KWH AND TON-HR

		MWH	TON-HR (000s)	COST ($)	COST/KWH (CENTS)	COST/TON- (CENTS)
CENTRAL						
CHILLER	DEMAND			13251408	9.52	7.14
	ENERGY			5498400	3.95	2.96
	TOTAL	139200	185600	18749808	13.47	10.10
TOWER	DEMAND			4767520	4.91	2.57
	ENERGY			3831500	3.95	2.06
	TOTAL	97000		8599020	8.86	4.63
TOTALS	DEMAND			18018928	7.63	9.71
	ENERGY			9329900	3.95	5.03
	TOTAL	236200	185600	27348828	11.58	14.74
COMP'T						
CHILLER	DEMAND			4389852	7.80	5.85
	ENERGY			2221875	3.95	2.96
	TOTAL	56250	75000	6611727	11.75	8.82
TOWER	DEMAND			1608320	4.60	2.14
	ENERGY			1382500	3.95	1.84
	TOTAL	35000		2990820	8.55	3.99
TOTALS	DEMAND			5998172	6.57	8.00
	ENERGY			3604375	3.95	4.81
	TOTAL	91250	75000	9602547	10.52	12.80
TOTAL						
	DEMAND			24017100	7.33	9.22
	ENERGY			12934275	3.95	4.96
	TOTAL	327450	260600	36951375	11.28	14.18

FIGURE 36

SUMMARY OF THE OWNING COST OF ON-SITE CHILLERS

Assumptions:
1. The lakewater cooling area presently includes some 700 chillers.
2. The Toronto Hydro 1991 rate will apply at $14.36/month/kW of demand and 3.95¢/kWh.
3. 560 chillers are assumed to be operated in conjunction with central type air handling systems and operate 1,160 equivalent full load hrs/yr.
4. 140 chillers will be for compartment type air handling systems and operate 1,875 full load hrs/yr.
5. Water tower fan and pumps will operate 2,300 full load hrs/yr. for central systems and 3,500 full load hrs/yr. for compartmented systems.
6. Space vacated by chillers is unrentable.
7. There will be no reduction in operator salaries.

ITEM	COST/TON YEAR		COST/TON HOUR		COST/SQ.FT./YEAR	
	CENTRAL $	COMPARTMENT $	CENTRAL $	COMPARTMENT $	CENTRAL $	COMPARTMENT $
ELECTRIC ENERGY	170.93	240.08	.147	.128	.427	.600
SERVICE CONTRACTS	10.00	10.00	.009	.005	.025	.025
TOWER CHEMICAL	5.00	6.00	.004	.003	.013	.015
TOWER WATER MAKEUP	4.00	6.00	.004	.003	.010	.015
REPAIR ALLOWANCE	5.00	5.00	.004	.003	.013	.013
SUB TOTAL	194.93	267.08	.168	.142	.488	.668
Amortization of new plant @ $800/ton @ 12%/year	96.00	96.00	.083	.051	.240	.240
TOTAL	290.93	363.08	.251	.193	.728	.908

FIGURE 37

LAKEWATER PUMPING ENERGY COST FOR CENTRAL SYSTEMS

BASED ON PROJECTED RATES IN 2000 FOR ULTIMATE CAPACITY OF 240000 TONS

COL.1 MONTH	COL.2 FULL LOAD HOURS	COL.3 MILLION GALLONS /MONTH	COL.4 MAXIMUM TONS/ MONTH	COL.5 GALLONS PER MINUTE PEAK	COL.6 GALLONS PER MINUTE AVERAGE	COL.7 NET PEAK MW	COL.8 NET AVE. MW	COL.9 ENERGY HOURS	COL.10 MWH	COL.11 DEMAND MW	COL.12 COST $/KW	COL.13 TOTAL ($)	COL.14 ENERGY MWH	COL.15 COST $/KWH	COL.16 TOTAL ($)	COL.17 GRAND TOTAL ($)
JAN	0	0	0	0	0	0.00	0.00	744	0	0.00	0.00	0	0	0.1293	0	0
FEB	0	0	0	0	0	0.00	0.00	674	0	0.00	0.00	0	0	0.1293	0	0
MAR	25	720	144000	288000	16129	7.10	0.50	744	372	5.00	14.52	72622	372	0.1293	48103	157848
										2.10	17.68	37124	0		0	
APR	75	2160	213600	427200	50000	13.50	1.10	720	792	5.00	11.95	59757	400	0.1104	44154	230545
										6.50	14.03	91171	392	0.0905	35463	
MAY	125	3600	232800	465600	80645	16.00	1.50	744	1116	5.00	11.95	59757	400	0.1104	44154	321086
										11.00	14.03	154290	400	0.0905	36186	
													316	0.0845	26699	
JUN'	175	5040	240000	480000	116667	16.50	2.50	720	1800	5.00	11.95	59757	400	0.1104	44154	385890
										11.50	14.03	161303	400	0.0905	36186	
													1000	0.0845	84490	
JUL	225	6480	240000	480000	145161	16.50	3.00	744	2232	5.00	11.95	59757	400	0.1104	44154	422390
										11.50	14.03	161303	400	0.0905	36186	
													1432	0.0845	120990	
AUG	200	5760	240000	480000	129032	16.50	2.80	744	2083	5.00	11.95	59757	400	0.1104	44154	409801
										11.50	14.03	161303	400	0.0905	36186	
													1283	0.0845	108401	
SEP	160	4608	220800	441600	106667	14.50	2.10	720	1512	5.00	11.95	59757	400	0.1104	44154	333504
										9.50	14.03	133250	400	0.0905	36186	
													712	0.0845	60157	
OCT	125	3600	213600	427200	80645	13.50	1.50	744	1116	5.00	14.52	72622	400	0.1293	51723	338758
										8.50	17.68	150264	400	0.1074	42959	
													216	0.0981	21190	
NOV	50	1440	100800	201600	33333	4.50	0.80	720	576	4.50	14.52	65359	400	0.1293	51723	135984
													176	0.1074	18902	
DEC	0	0	0	0	0	0.00	0.00	744	0	0.00	0.00	0	0	0.1293	0	0
	1160	33408	1845600	3691200		119			11599	116.60		1619154	11499		1116653	2735806

FIGURE ~~10~~ 39

LAKEWATER PUMPING ENERGY COST FOR COMPARTMENTAL SYSTEMS

BASED ON PROJECTED RATES IN 2000 FOR ULTIMATE 60000 TON CAPACITY

COL.1	COL.2	COL.3	COL.4	COL.5	COL.6	COL.7	COL.8	COL.9	COL.10	COL.11	COL.12	COL.13	COL.14	COL.15	COL.16	COL.17
										ENERGY COST USING TORONTO HYDRO TIME-OF-DAY RATES						
	FULL LOAD	MILLION GALLONS	MAXIMUM TONS	GALLONS PER MINUTE		EXTRA PEAK MW	AVE. MW	ENERGY		DEMAND			ENERGY			TOTAL
MONTH	HOURS	/MONTH	/MONTH	PEAK	AVERAGE	DEMAND	DEMAND	HOURS	MWH	MW	$/MW	COST ($)	MWH	$/KWH	COST ($)	COST ($)
JAN	100	720	39000	78000	16129	1.50	0.50	744	372	1.50	14.52	21786	372	0.1293	48103	69889
FEB	100	720	39000	78000	17857	1.50	0.50	672	336	1.50	14.52	21786	336	0.1293	43447	65234
MAR	125	900	48600	97200	20161	4.40	0.50	744	372	4.40	14.52	63907	372	0.1293	48103	112009
APR	150	1080	53400	106800	25000	6.00	0.50	720	360	5.00	11.95	59757	360	0.1104	39739	113522
										1.00	14.03	14026			0	
MAY	175	1260	58200	116400	28226	6.50	0.60	744	446	5.00	11.95	59757	400	0.1104	44154	129112
										1.50	14.03	21040	46	0.0905	4161	
JUN	200	1440	60000	120000	33333	8.00	0.80	720	576	5.00	11.95	59757	400	0.1104	44154	161912
										3.00	14.03	42079	176	0.0905	15922	
JUL	250	1800	60000	120000	40323	8.00	0.90	744	670	5.00	11.95	59757	400	0.1104	44154	170416
										3.00	14.03	42079	270	0.0905	24426	
AUG	225	1620	60000	120000	36290	8.00	0.80	744	595	5.00	11.95	59757	400	0.1104	44154	163631
										3.00	14.03	42079	195	0.0905	17641	
SEP	175	1260	55200	110400	29167	7.00	0.70	720	504	5.00	11.95	59757	400	0.1104	44154	141372
										2.00	14.03	28053	104	0.0905	9408	
OCT	150	1080	53400	106800	24194	6.50	0.50	744	372	5.00	14.52	72622	372	0.1293	48103	147241
										1.50	17.68	26517			0	
NOV	125	900	45600	91200	20833	3.00	0.50	720	360	3.00	14.52	43573	360	0.1293	46551	90124
DEC	100	720	39000	78000	16129	1.50	0.50	744	372	1.50	14.52	21786	372	0.1293	48103	69889
	1875	13500				61.90			5335			819877			614475	1434351

NET PUMPING ENERGY COST: 4170158

FIGURE ~~27~~ 37

LAKEWATER PUMPING ENERGY COST FOR CENTRAL SYSTEMS

BASED ON PROJECTED RATES IN 2000 FOR ULTIMATE CAPACITY OF 240000 TONS

COL.1 MONTH	COL.2 FULL LOAD HOURS	COL.3 MILLION GALLONS /MONTH	COL.4 MAXIMUM TONS/ MONTH	COL.5 GALLONS PER MINUTE PEAK	COL.6 GALLONS PER MINUTE AVERAGE	COL.7 NET PEAK MW	COL.8 NET AVE. MW	COL.9 ENERGY HOURS	COL.10 MWH	COL.11 DEMAND MW	COL.12 COST $/KW	COL.13 TOTAL ($)	COL.14 ENERGY MWH	COL.15 COST $/KWH	COL.16 TOTAL ($)	COL.17 GRAND TOTAL ($)
JAN	0	0	0	0	0	0.00	0.00	744	0	0.00	0.00	0	0	0.1293	0	
FEB	0	0	0	0	0	0.00	0.00	674	0	0.00	0.00	0	0	0.1293	0	
MAR	25	720	144000	288000	16129	7.10	0.50	744	372	5.00	14.52	72622	372	0.1293	48103	15784
										2.10	17.68	37124	0		0	
APR	75	2160	213600	427200	50000	13.50	1.10	720	792	5.00	11.95	59757	400	0.1104	44154	23054
										6.50	14.03	91171	392	0.0905	35463	
MAY	125	3600	232800	465600	80645	16.00	1.50	744	1116	5.00	11.95	59757	400	0.1104	44154	5210
										11.00	14.03	154290	400	0.0905	36186	
													316	0.0845	26699	
JUN	175	5040	240000	480000	116667	16.50	2.50	720	1800	5.00	11.95	59757	400	0.1104	44154	3858
										11.50	14.03	161303	400	0.0905	36186	
													1000	0.0845	84490	
JUL	225	6480	240000	480000	145161	16.50	3.00	744	2232	5.00	11.95	59757	400	0.1104	44154	4225
										11.50	14.03	161303	400	0.0905	36186	
													1432	0.0845	120990	
AUG	200	5760	240000	480000	129032	16.50	2.80	744	2083	5.00	11.95	59757	400	0.1104	44154	40980
										11.50	14.03	161303	400	0.0905	36186	
													1283	0.0845	108401	
SEP	160	4608	220800	441600	106667	14.50	2.10	720	1512	5.00	11.95	59757	400	0.1104	44154	33550
										9.50	14.03	133250	400	0.0905	36186	
													712	0.0845	60157	
OCT	125	3600	213600	427200	80645	13.50	1.50	744	1116	5.00	14.52	72622	400	0.1293	51723	3307
										8.50	17.68	150264	400	0.1074	42959	
													216	0.0981	21190	
NOV	50	1440	100800	201600	33333	4.50	0.80	720	576	4.50	14.52	65359	400	0.1293	51723	1359
													176	0.1074	18902	
DEC	0	0	0	0	0	0.00	0.00	744	0	0.00	0.00	0	0	0.1293	0	
	1160	33408	1845600	3691200		119			11599	116.60		1619154	11499		1116653	273580

FIGURE ~~18~~ 38

LAKEWATER PUMPING ENERGY COST FOR COMPARTMENTAL SYSTEMS

BASED ON PROJECTED RATES IN 2000 FOR ULTIMATE 60000 TON CAPACITY

COL.1	COL.2	COL.3	COL.4	COL.5	COL.6	COL.7	COL.8	COL.9	COL.10	COL.11	COL.12	COL.13	COL.14	COL.15	COL.16	COL.17
										ENERGY COST USING TORONTO HYDRO TIME-OF-DAY RATES						
										DEMAND			ENERGY			
MONTH	FULL LOAD HOURS	MILLION GALLONS /MONTH	MAXIMUM TONS /MONTH	GALLONS PER MINUTE PEAK	GALLONS PER MINUTE AVERAGE	EXTRA PEAK MW DEMAND	AVE. MW DEMAND	ENERGY HOURS	MWH	MW	$/MW	COST ($)	MWH	$/KWH	COST ($)	TOTAL COST ($)
JAN	100	720	39000	78000	16129	1.50	0.50	744	372	1.50	14.52	21786	372	0.1293	48103	69889
FEB	100	720	39000	78000	17857	1.50	0.50	672	336	1.50	14.52	21786	336	0.1293	43447	65234
MAR	125	900	48600	97200	20161	4.40	0.50	744	372	4.40	14.52	63907	372	0.1293	48103	112009
APR	150	1080	53400	106800	25000	6.00	0.50	720	360	5.00	11.95	59757	360	0.1104	39739	113522
										1.00	14.03	14026			0	
MAY	175	1260	58200	116400	28226	6.50	0.60	744	446	5.00	11.95	59757	400	0.1104	44154	129112
										1.50	14.03	21040	46	0.0905	4161	
JUN	200	1440	60000	120000	33333	8.00	0.80	720	576	5.00	11.95	59757	400	0.1104	44154	161912
										3.00	14.03	42079	176	0.0905	15922	
JUL	250	1800	60000	120000	40323	8.00	0.90	744	670	5.00	11.95	59757	400	0.1104	44154	170416
										3.00	14.03	42079	270	0.0905	24426	
AUG	225	1620	60000	120000	36290	8.00	0.80	744	595	5.00	11.95	59757	400	0.1104	44154	163631
										3.00	14.03	42079	195	0.0905	17641	
SEP	175	1260	55200	110400	29167	7.00	0.70	720	504	5.00	11.95	59757	400	0.1104	44154	141372
										2.00	14.03	28053	104	0.0905	9408	
OCT	150	1080	53400	106800	24194	6.50	0.50	744	372	5.00	14.52	72622	372	0.1293	48103	147241
										1.50	17.68	26517			0	
NOV	125	900	45600	91200	20833	3.00	0.50	720	360	3.00	14.52	43573	360	0.1293	46551	90124
DEC	100	720	39000	78000	16129	1.50	0.50	744	372	1.50	14.52	21786	372	0.1293	48103	69889
	1875	13500				61.90			5335			819877			614475	1434351

NET PUMPING ENERGY COST: 4170158

Figure 39

Lakewater Pumping Head

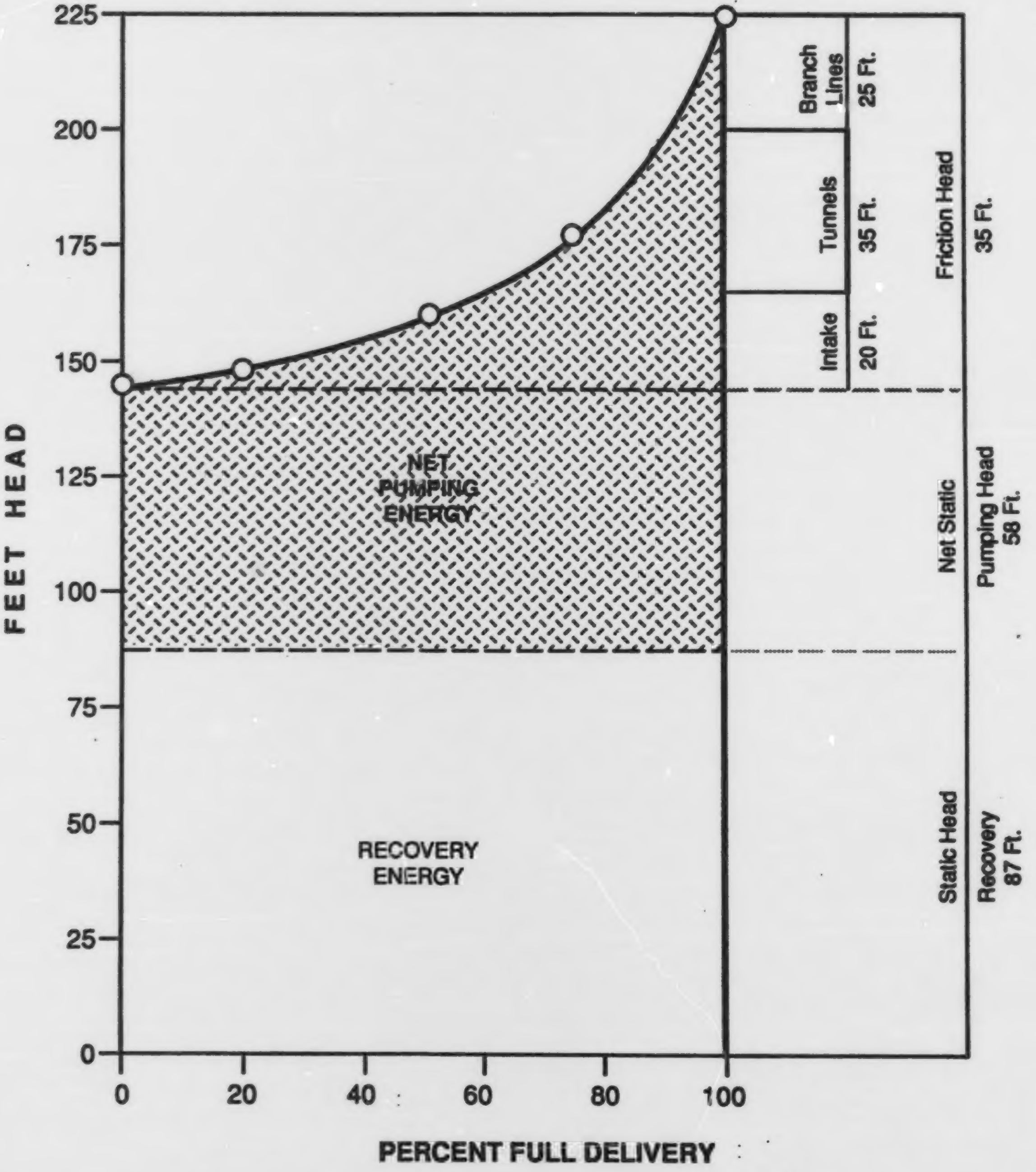


Figure 40

Lakewater Pumping Energy

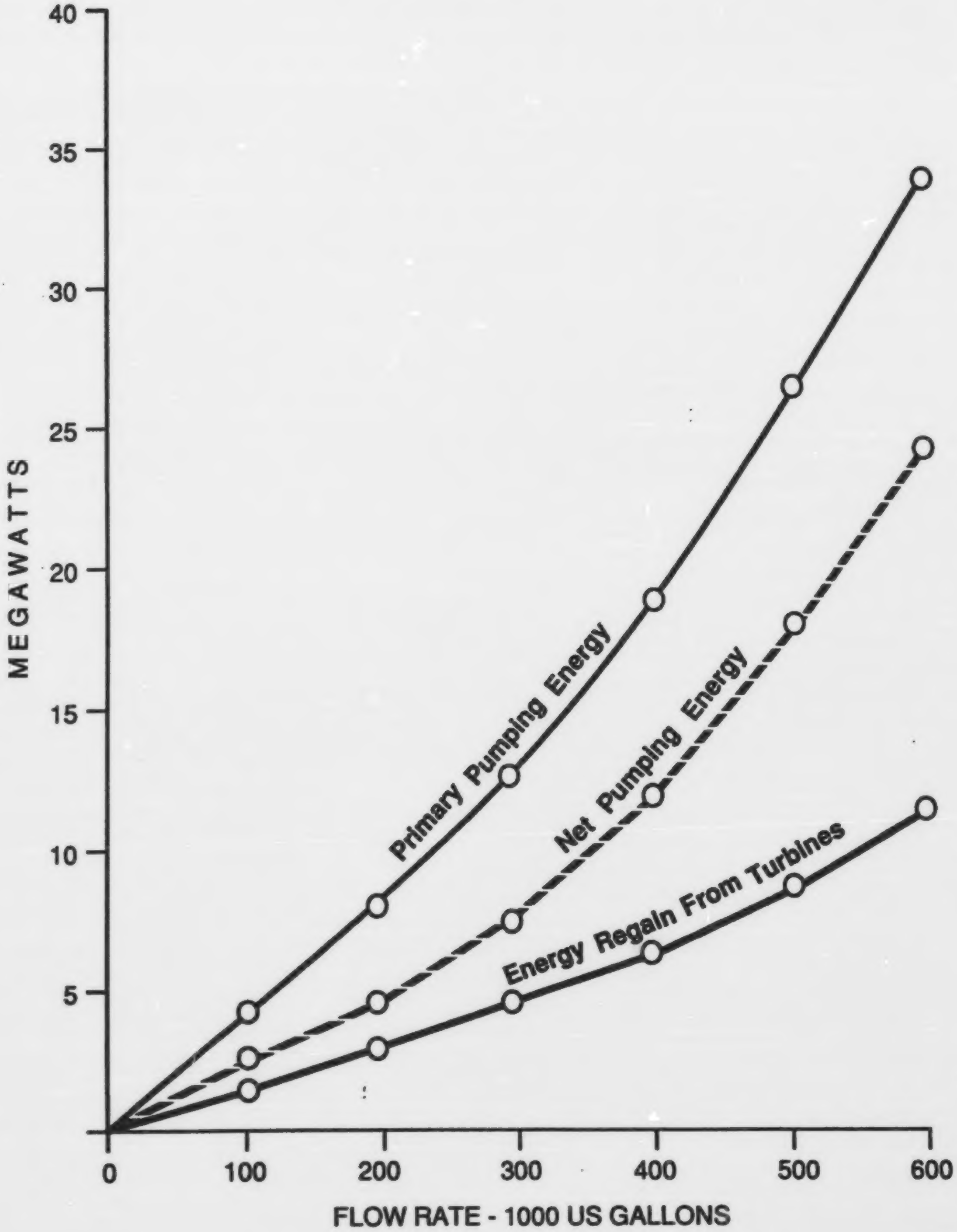


Figure 41

Energy Factor for Lakewater Pumps

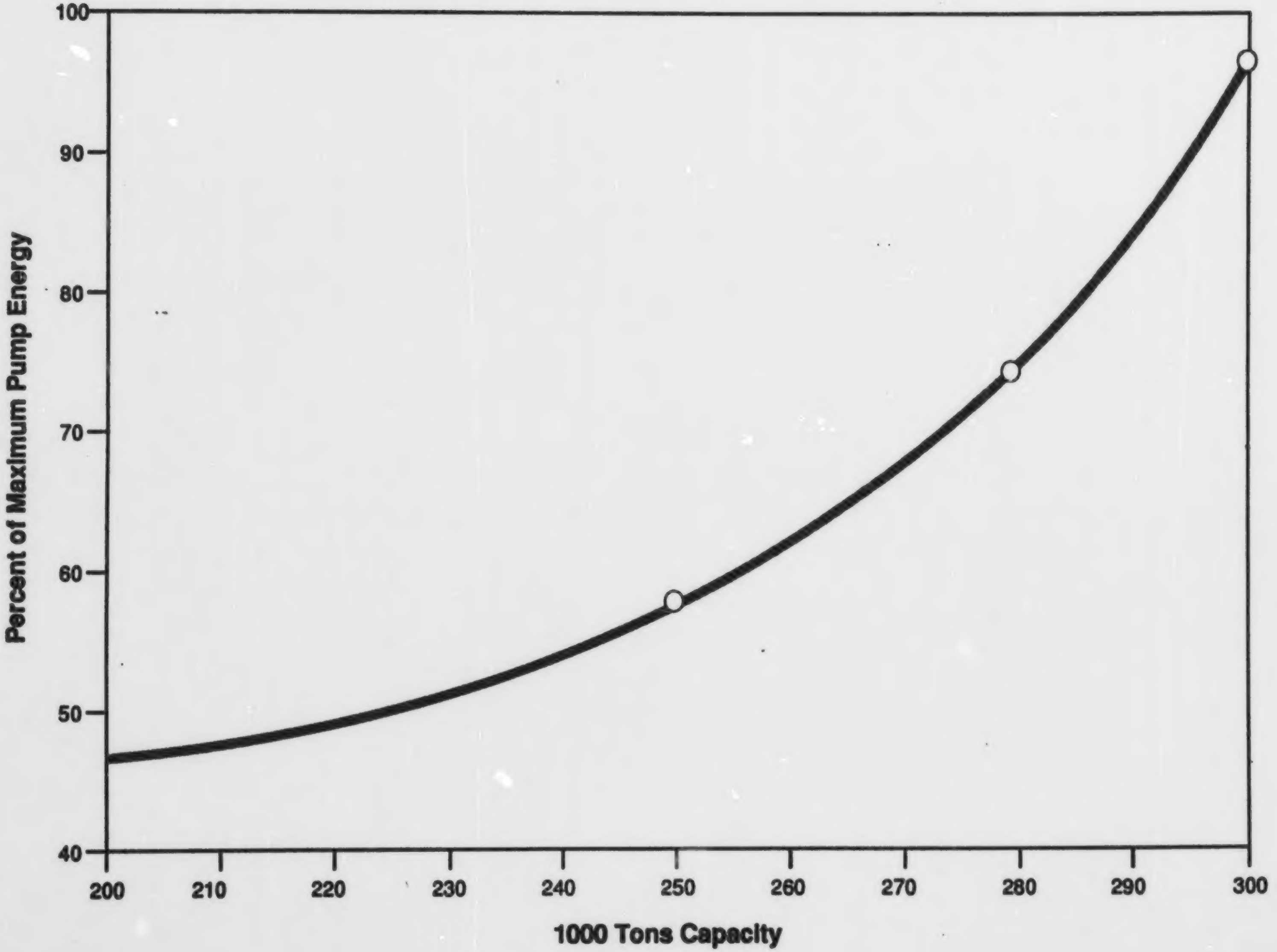


FIGURE ~~24~~ A2

COST OF AMORTIZING NEW CHILLERS

COL.1 YEAR	COL.2 COOLING CAPACITY TONS	COL.3 ADDED CAPACITY 1.7%/YR	COL.4 TOTAL CAP. ADDED	COL.5 CHILLER COST PER TON ($)	COL.6 VALUE OF ADDED CAPACITY ($000)	COL.7 CUMULATIVE ADDED CAPACITY ($000)	COL.8 AMORTIZED @10.6% ($000)
1991	200000	3400	3400	800	2720	2720	288
1992	203400	3458	6858	840	2905	5625	596
1993	206858	3517	10374	882	3102	8726	925
1994	210374	3576	13951	926	3312	12038	1276
1995	213951	3637	17588	972	3537	15575	1651
1996	217588	3699	21287	1021	3777	19352	2051
1997	221287	3762	25049	1072	4033	23385	2479
1998	225049	3826	28875	1126	4307	27691	2935
1999	228875	3891	32765	1182	4599	32290	3423
2000	232765	3957	36722	1241	4911	37201	3943
2001	236722	4024	40747	1303	5244	42445	4499
2002	240747	4093	44839	1368	5600	48045	5093
2003	244839	4162	49002	1437	5980	54025	5727
2004	249002	4233	53235	1509	6386	60411	6404
2005	253235	4305	57540	1584	6819	67230	7126
2006	257540	4378	61918	1663	7282	74511	7898
2007	261918	4453	66371	1746	7776	82287	8722
2008	266371	4528	70899	1834	8303	90590	9603
2009	270899	4605	75504	1925	8867	99456	10542
2010	275504	4684	80188	2022	9468	108925	11546
2011	280188	4763	84951	2123	10111	119035	12618
2012	284951	4844	89795	2229	10797	129832	13762
2013	289795	4927	94722	2340	11529	141361	14984
2014	294722	5010	99732	2457	12311	153672	16289
2015	299732	268	100000	2580	691	154363	16363
2016	300000	0	100000		0	154363	16363
2017	300000	0	100000		0	154363	16363
2018	300000	0	100000		0	154363	16363
2019	300000	0	100000		0	154363	16363
2020	300000	0	100000		0	154363	16363
2021	300000	0	100000		0	154363	16363
2022	300000	0	100000		0	154363	16363
2023	300000	0	100000		0	154363	16363
2024	300000	0	100000		0	154363	16363
2025	300000	0	100000		0	154363	16363
2026	300000	0	100000		0	154363	16363
2027	300000	0	100000		0	154363	16363
2028	300000	0	100000		0	154363	16363
2029	300000	0	100000		0	154363	16363
2030	300000	0	100000		0	154363	16363
2031	300000	0	100000		0	154363	16363
2032	300000	0	100000		0	154363	16363
2033	300000	0	100000		0	154363	16363
2034	300000	0	100000		0	154363	16363
2035	300000	0	100000		0	154363	16363
2036	300000	0	100000		0	154363	16363
2037	300000	0	100000		0	154363	16363
2038	300000	0	100000		0	154363	16363
2039	300000	0	100000		0	154363	16363
2040	300000	0	100000		0	154363	16363

FIGURE ~~24A~~ 43

COST OF OPERATING ADDED CHILLER CAPACITY

COL.1	COL.2	COL.3	COL.4	COL.5	COL.6	COL.7
	ADDED CHILLER	ELECTRICITY COST		SERVICING COST		TOTAL COST
YEAR	TONS	$ PER TON-YR	$000	$ PER TON	$000	($000)
1991	3400	184.8	628	25.0	85	713
1992	6858	194.0	1330	26.3	180	1510
1993	10374	203.7	2113	27.6	286	2399
1994	13951	213.9	2984	28.9	404	3388
1995	17588	224.6	3950	30.4	534	4484
1996	21287	235.8	5020	31.9	679	5699
1997	25049	247.6	6202	33.5	839	7041
1998	28875	260.0	7507	35.2	1016	8522
1999	32765	273.0	8944	36.9	1210	10154
2000	36722	286.6	10526	38.8	1424	11950
2001	40747	301.0	12263	40.7	1659	13922
2002	44839	316.0	14169	42.8	1917	16087
2003	49002	331.8	16259	44.9	2200	18459
2004	53235	348.4	18547	47.1	2510	21056
2005	57540	365.8	21049	49.5	2848	23897
2006	61918	384.1	23783	52.0	3218	27001
2007	66371	403.3	26768	54.6	3622	30390
2008	70899	423.5	30024	57.3	4063	34086
2009	75504	444.6	33573	60.2	4543	38115
2010	80188	466.9	37438	63.2	5066	42504
2011	84951	490.2	41645	66.3	5635	47280
2012	89795	514.7	46221	69.6	6254	52475
2013	94722	540.5	51194	73.1	6927	58121
2014	99732	567.5	56597	76.8	7658	64256
2015	100000	595.9	59587	80.6	8063	67650
2016	100000	625.7	62566	84.7	8466	71032
2017	100000	656.9	65695	88.9	8889	74584
2018	100000	689.8	68979	93.3	9334	78313
2019	100000	724.3	72428	98.0	9800	82229
2020	100000	760.5	76050	102.9	10290	86340
2021	100000	798.5	79852	108.0	10805	90657
2022	100000	838.4	83845	113.5	11345	95190
2023	100000	880.4	88037	119.1	11912	99949
2024	100000	924.4	92439	125.1	12508	104947
2025	100000	970.6	97061	131.3	13133	110194
2026	100000	1019.1	101914	137.9	13790	115704
2027	100000	1070.1	107010	144.8	14480	121489
2028	100000	1123.6	112360	152.0	15204	127564
2029	100000	1179.8	117978	159.6	15964	133942
2030	100000	1238.8	123877	167.6	16762	140639
2031	100000	1300.7	130071	176.0	17600	147671
2032	100000	1365.7	136574	184.8	18480	155054
2033	100000	1434.0	143403	194.0	19404	162807
2034	100000	1505.7	150573	203.7	20374	170947
2035	100000	1581.0	158102	213.9	21393	179495
2036	100000	1660.1	166007	224.6	22463	188470
2037	100000	1743.1	174307	235.9	23586	197893
2038	100000	1830.2	183023	247.6	24765	207788
2039	100000	1921.7	192174	260.0	26003	218177
2040	100000	2017.8	201783	273.0	27303	229086

Figure 44

Construction Schedule 1

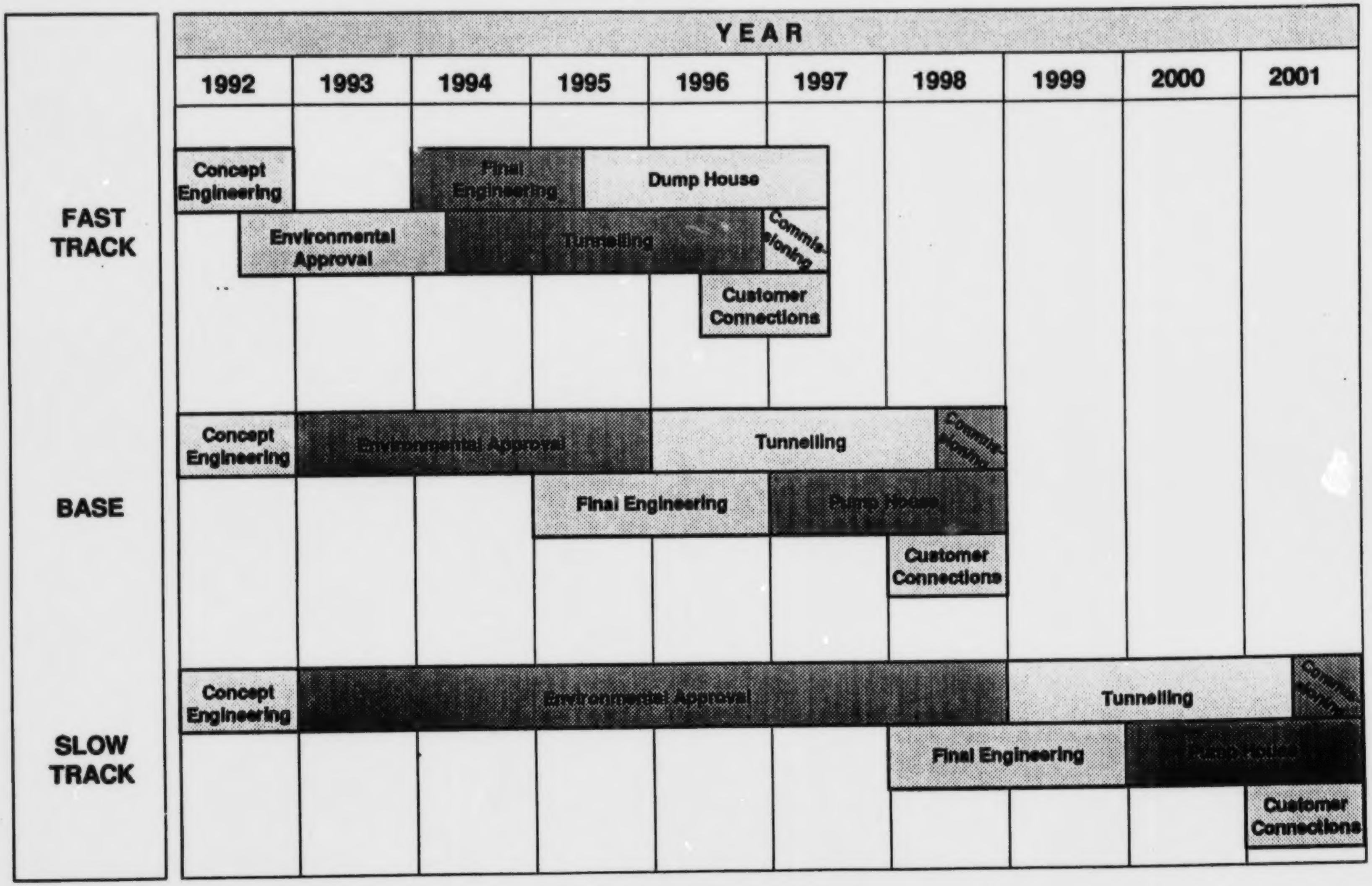


FIGURE ~~23~~ 45.

CALCULATION OF INITIAL COST ($ 000) BASE CASE

COL.1	COL.2	COL.3	COL.4	COL.5	COL.6	COL.7	COL.8	COL.9	COL.10	COL.11	COL.12	COL.13
	ENGINEERING COSTS											
YEAR	MECH. & ELECTRIC	ENV. STUDIES	LEGAL	CONTRACT	CONTINGENCY	HEAT EX.	CUSTOMER CONN'S	CUSTOMER ENG.	15% TAXES	TOTAL	INTEREST MULTIPLIER	TOTAL
1992	5000	1000	100	0	0	0	0	0	915	7015	1.95	13670.3
1993	1000	1000	100	0	0	0	0	0	315	2415	1.77	4278.3
1994	1000	1000	100	0	0	0	0	0	315	2415	1.61	3889.4
1995	7000	0	100	0	0	0	0	0	1065	8165	1.46	11954.4
1996	7000	0	100	77000	7500	0	0	0	13740	105340	1.33	140207.5
1997	1500	0	100	81000	8000	0	0	0	13590	104190	1.21	126069.9
1998	1500	0	100	85000	8500	33500	107200	10000	36870	282670	1.10	310937.0
TOTAL	24000	3000	700	243000	24000	33500	107200	10000	66810	512210		611006.8

ONTARIO HYDRO INCENTIVE FOR YEAR 1999 ($591/TON, 228875 TONS)		135265.0
NET INITIAL COST:		475741.8
COST OF INTERIM FINANCE:	(611007-512210)	98796.8

FIGURE 46
OPERATING COST OF CUSTOMERS' ORIGINAL ON-SITE COOLING PLANT

ALL AMOUNTS IN $000

COL. 1 YEAR	COL. 2 ELECTRICITY COSTS CENTRAL (160,000 TONS)	COL. 3 ELECTRICITY COSTS COMP'T (40,000 TONS)	COL. 4 ELECTRICITY COSTS 80/20 BLEND TOTAL	COL. 5 SERVICING COSTS CENTRAL	COL. 6 SERVICING COSTS COMP'T	COL. 7 80/20 BLEND TOTAL	COL. 8 AMORTIZED ORIGINAL 200 KTONS @ 10.6%	COL. 9 INITIAL SYSTEM COST	COL. 10 ADDED CHILLER CAPACITY COSTS $000 AMORTIZED CAPACITY	COL. 11 ADDED CHILLER CAPACITY COSTS $000 OPERATING COSTS	COL. 12 NET COST SUM OF COLS. 9 TO 11	COL. 13 CENTS PER TON-HR	COL. 14 PRESENT WORTH FOR YEAR 10% FACTOR	COL. 15 PRESENT WORTH FOR YEAR (M $000)
1991	27349	9603	36952	3840	1120	4960	16973	58885	288	713	59887	22.98		
1992	28716	10085	38800	4032	1176	5208	16973	60981	596	1510	63087	23.00		
1993	30152	10587	40740	4254	1214	5468	16973	63181	925	2399	66505	24.67		
1994	31660	11117	42777	4445	1297	5742	16973	65491	1276	3388	70155	25.59		
1995	33243	11673	44915	4668	1361	6029	16973	67917	1651	4484	74055	26.56		
1996	34905	12256	47161	4901	1429	6330	16973	70465	2051	5699	78215	27.59		
1997	36650	12869	49519	5146	1501	6647	16973	73139	2479	7041	82659	28.67		
1998	38483	13512	51995	5403	1576	6979	16973	75947	2935	8522	87404	29.81		
1999	40407	14188	54595	5673	1655	7328	16973	78896	3425	10154	92475	31.01	1.00	[illegible]
2000	42427	14897	57325	5957	1737	7695	16973	81992	3943	11150	97085	32.27	0.90	[illegible]
2001	44549	15642	60191	6255	1824	8079	16973	85243	4499	13923	103665	33.61	0.81	[illegible]
2002	46776	16424	63200	6568	1916	8483	16973	88657	5093	16087	109836	35.01	0.73	[illegible]
2003	49115	17246	66360	6896	2011	8907	16973	92241	5727	18459	116426	36.49	0.66	[illegible]
2004	51571	18108	69679	7241	2112	9353	16973	96004	6404	21056	123464	38.05	0.59	[illegible]
2005	54149	19013	73162	7603	2218	9820	16973	99956	7126	23897	130979	39.69	0.55	[illegible]
2006	56857	19964	76821	7785	2526	10311	16973	104105	7890	27009	139004	41.42	0.48	[illegible]
2007	59699	20963	80662	8382	2445	10827	16973	108462	8722	30390	147574	43.24	0.43	[illegible]
2008	62684	22010	84695	8801	2567	11368	16973	113036	9605	34086	156725	45.16	0.39	[illegible]
2009	65819	23111	88929	9241	2696	11937	16973	117839	10542	38116	166497	47.17	0.35	[illegible]
2010	69110	24266	93376	9703	2850	12554	16973	122903	11546	42504	176952	49.24	0.31	[illegible]
2011	72565	25480	98045	10189	2971	13160	16973	128178	12618	47280	188076	51.52	0.28	[illegible]
2012	76193	26754	102947	10698	3120	13819	16973	133739	13762	52475	199975	55.80	0.25	[illegible]
2013	80005	28091	108094	11233	3276	14509	16973	139577	14984	58121	212682	56.52	0.23	[illegible]
2014	84005	29494	113499	11795	3440	15235	16973	145707	16289	64255	226251	58.92	0.21	[illegible]
2015	88203	30971	119174	12384	3612	15996	16973	152143	16363	67650	236155	60.47	0.19	[illegible]
2016	92636	32519	125155	13004	3795	16799	16973	158927	16363	71007	246297	63.01	0.17	[illegible]
2017	97244	34145	131389	13654	3902	17556	16973	165918	16363	74664	256945	65.75	0.15	[illegible]
2018	102106	[illegible]	137959	14330	4181	18510	16973	175450	16363	76312	268125	69.64	0.14	[illegible]
2019	107212	37645	144857	15053	4391	19444	16973	181277	16363	81429	279069	71.59	0.12	[illegible]
2020	112572	39527	152099	15806	4610	20416	16973	189488	16363	86340	292191	74.75	0.11	[illegible]
2021	118201	41504	159704	16596	4841	21437	69862	251003	16363	88669	356035	91.14	0.10	[illegible]
2022	124111	43519	167630	17426	5063	22489	69862	260060	16363	95193	371615	95.07	0.09	[illegible]
2023	130510	45750	176074	18296	5538	23834	69862	269770	16363	99669	385802	98.72	0.08	[illegible]
2024	[illegible]	48040	184078	19212	5604	24816	69862	278756	16363	104947	400066	102.55	0.07	[illegible]
2025	143674	50448	194122	20173	5884	26056	69862	290040	16363	110194	416597	106.57	0.06	[illegible]
2026	150858	52970	203828	21101	6258	27359	69862	301049	16363	115704	433116	110.00	0.06	[illegible]
2027	158400	55619	214019	22241	6486	28727	69862	312608	16363	121489	450460	115.24	0.05	[illegible]
2028	166320	58400	224720	23553	6611	30164	69862	324746	16363	127564	468672	119.90	0.05	[illegible]
2029	174636	61320	235956	24520	7152	31672	69862	337490	16363	133942	487794	124.79	0.04	[illegible]
2030	183368	64386	247754	25746	7510	33256	69862	350872	16363	140639	507875	129.92	0.04	[illegible]
2031	192537	67605	260142	27034	7884	34918	69862	364922	16363	147671	528956	135.32	0.03	[illegible]
2032	202163	70986	273149	28385	8279	36664	69862	379675	16363	155054	551092	140.90	0.03	[illegible]
2033	212272	74535	286806	29804	8693	38497	69862	395165	16363	162807	574335	146.93	0.03	[illegible]
2034	222885	78261	301146	31295	9128	40423	69862	411431	16363	170947	598741	153.17	0.03	[illegible]
2035	234030	82174	316204	32859	9584	42443	69862	428509	16363	179495	624367	159.73	0.02	[illegible]
2036	245731	86283	332014	34502	10064	44566	69862	446442	16363	188470	651274	166.61	0.02	[illegible]
2037	258018	90597	348615	36228	10566	46794	69862	465271	16363	197893	679526	173.64	0.02	[illegible]
2038	270918	95127	366045	38059	11075	49134	69862	485041	16363	207788	709191	181.43	0.02	[illegible]
2039	284464	99884	384348	39941	11649	51590	69862	505800	16363	218177	740340	189.54	0.01	[illegible]
2040	298887	104678	403565	41938	12232	54170	69862	527597	16363	229085	773045	197.76	0.01	[illegible]
TOTAL	5725450	2010369	7735827	605896	254470	[illegible]	1906430	10600625	579807	4001319	15261749			[illegible]

NOTES: SINKING FUND ENDS AFTER TENTH YEAR
AMORTIZATION OF NEW CHILLERS BEGINS BEFORE ELEVENTH YEAR
BASED ON $1305/TON FOR CHILLERS AFTER TENTH YEAR
AMORTIZATION TERM IS 25 YEARS

FIGURE 47
COST OF LAKEWATER COOLING. BASE CASE

								HEAT EXCHANGERS		HEAT EX. AMORTIZED		ADMIN. COSTS $000		HYDRO INCENTIVES		NET COSTS			
COL.1 YEAR	COL.2 SYSTEM TONS	COL.3 MILLION TON-HOURS	COL.4 500 K-TON ENERGY ($ 000)	COL.5 PUMP NORM. FACTOR	COL.6 ACTUAL ENERGY ($ 000)	COL.7 PLANT COST AMORTIZED ($ 000)	COL.8 TONS	COL.9 TOTAL NEW TONS	COL.10 COST/NEW TON ($)	COL.11 ANNUAL COST $000	COL.12 TOTAL COST $000	COL.13 SALARIES	COL.14 REPAIRS, ETC.	COL.15 INCENTIVE $ PER TON	COL.16 TOTAL ($000)	COL.17 COL.6+7+12TO14-16 ($000)	COL.18 TOTAL CENTS/TON-HR	COL.19 COST 10% INT FACTOR	COL. [illegible]
1999	228075	498.22	3971	0.509	2021	48526	5325	5325	176	71	71	369	295	591	2261	49022	16.44	1.00	[illegible]
2000	232705	503.29	4170	0.518	2160	48526	2390	7716	185	76	147	388	310	621	2414	49117	16.19	0.90	[illegible]
2001	236722	508.45	4379	0.530	2321	48526	3957	11673	194	81	229	407	326	652	2576	49250	15.96	0.81	[illegible]
2002	240747	513.69	4597	0.545	2506	48526	4024	15697	204	87	316	428	342	684	2755	49365	15.74	0.73	[illegible]
2003	244054	519.03	4827	0.567	2737	48526	4093	19790	214	93	408	449	359	718	2940	49539	15.53	0.66	[illegible]
2004	249002	524.45	5069	0.591	2996	48526	4162	23952	224	99	507	471	377	754	3139	49738	15.33	0.59	[illegible]
2005	253275	529.96	5322	0.613	3262	48526	4233	28185	236	106	613	495	396	792	3352	49940	15.13	0.53	[illegible]
2006	257540	535.57	5588	0.642	3588	48526	4305	32490	247	113	726	520	416	832	3590	50195	14.96	0.48	[illegible]
2007	261919	541.20	5868	0.670	3931	48526	4378	36868	260	121	847	546	437	873	3823	50465	14.79	0.43	[illegible]
2008	266371	547.08	6161	0.699	4307	48526	4453	41321	273	129	976	573	459	917	4092	50757	14.62	0.39	[illegible]
2009	270849	552.98	6469	0.729	4716	48526	4528	45849	287	138	1113	602	481	963	4359	51079	14.47	0.35	[illegible]
2010	275504	558.98	6792	0.761	5169	48526	4605	50455	301	147	1260	632	505	1011	4655	51457	14.33	0.31	[illegible]
2011	280159	565.08	7132	0.802	5720	48526	4684	55138	316	157	1417	663	531	1061	4971	51886	14.21	0.28	[illegible]
2012	284951	571.29	7489	0.851	6375	48526	4763	59901	332	167	1584	696	557	1114	5309	52428	14.12	0.25	[illegible]
2013	289785	577.60	7865	0.900	7077	48526	4844	64745	349	179	1763	731	585	1170	5669	53014	14.04	0.23	[illegible]
2014	294722	584.02	8256	0.949	7835	48526	4927	69672	366	191	1954	768	614	1229	6053	53644	13.97	0.21	[illegible]
2015	299752	590.55	8669	0.999	8660	48526	5010	74682	384	204	2158	806	645	1290	6463	54332	13.91	0.19	[illegible]
2016	300000	590.90	9105	1.000	9105	48526	260	74950	403	11	2169	847	677	1355	363	60958	15.59	0.17	[illegible]
2017	300000	590.90	9558	1.000	9558	48526	0	74950	423	0	2169	889	711	1422	0	61853	15.82	0.15	[illegible]
2018	300000	590.90	10036	1.000	10036	48526	0	74950	444	0	2169	933	747	1493	0	62411	15.97	0.14	[illegible]
2019	300000	590.90	10537	1.000	10537	48526	0	74950	467	0	2169	980	784	1568	0	62996	16.12	0.12	[illegible]
2020	300000	590.90	11064	1.000	11064	48526	0	74950	490	0	2169	1029	823	1646	0	63611	16.27	0.11	[illegible]
2021	300000	590.90	11617	1.000	11617	48526	0	74950	515	0	2169	1080	864	1729	0	64257	16.44	0.10	[illegible]
2022	300000	590.90	12198	1.000	12198	48526	0	74950	540	0	2169	1135	908	1815	0	64939	16.61	0.09	[illegible]
2023	300000	590.90	12808	1.000	12808	48526	0	74950	567	0	2169	1191	953	1906	0	65647	16.79	0.08	[illegible]
2024	300000	590.90	13449	1.000	13449	48526	0	74950	596	0	2169	1251	1001	2001	0	66396	16.98	0.07	[illegible]
2025	300000	590.90	14121	1.000	14121	48526	0	74950	625	0	2169	1313	1051	2101	0	67180	17.19	0.06	[illegible]
2026	300000	590.90	14827	1.000	14827	48526	0	74950	657	0	2169	1379	1103	2206	0	68004	17.40	0.06	[illegible]
2027	300000	590.90	15569	1.000	15569	48526	0	74950	690	0	2169	1448	1158	2317	0	68870	17.62	0.05	[illegible]
2028	300000	590.90	16347	1.000	16347	48526	0	74950	724	0	2098	1520	1216	2433	0	69707	17.83	0.05	[illegible]
2029	300000	590.90	17164	1.000	17164	48526	0	74950	760	0	2022	1596	1277	2554	0	70585	18.06	0.04	[illegible]
2030	300000	590.90	18022	1.000	18022	48526	0	74950	798	0	1941	1676	1341	2682	0	71506	18.29	0.04	[illegible]
2031	300000	590.90	18924	1.000	18924	48526	0	74950	838	0	1854	1760	1408	2816	0	72471	18.54	0.03	[illegible]
2032	300000	590.90	19870	1.000	19870	48526	0	74950	880	0	1761	1848	1478	2957	0	73483	18.80	0.03	[illegible]
2033	300000	590.90	20863	1.000	20863	48526	0	74950	924	0	1662	1940	1552	3105	0	74544	19.07	0.03	[illegible]
2034	300000	590.90	21906	1.000	21906	48526	0	74950	970	0	1556	2037	1630	3260	0	75656	19.35	0.03	[illegible]
2035	300000	590.90	23002	1.000	23002	48526	0	74950	1019	0	1445	2139	1711	3423	0	76821	19.65	0.02	[illegible]
2036	300000	590.90	24152	1.000	24152	48526	0	74950	1070	0	1323	2246	1797	3594	0	78043	19.97	0.02	[illegible]
2037	300000	590.90	25359	1.000	25359	48526	0	74950	1123	0	1194	2354	1887	3774	0	79324	20.29	0.02	[illegible]
2038	300000	590.90	26627	1.000	26627	48526	0	74950	1179	0	1056	2476	1981	3962	0	80667	20.64	0.02	[illegible]
2039	300000	590.90	27959	1.000	27959	48526	0	74950	1238	0	909	2600	2080	4161	0	82074	21.00	0.01	[illegible]
2040	300000	590.90	29357	1.000	29357	0	0	74950	1300	0	755	2730	2184	4369	0	35024	8.96	0.01	[illegible]
TOTAL		19295.02			507797	1941026						49980	38664		64503	2532196			4710.

NOTES:
1. PUMP ENERGY IS NOT PROPORTIONAL TO SYSTEM TONS.
LARGER TONNAGES ARE PUMPED AT GREATER FRICTION FACTOR.
SEE FIGURE 10 FOR FRICTION CURVE.
2. FRICTION CURVE BASED ON 300000 TON SIZING

Figure 48

Comparison of Accumulated Operating Cost

Base Case

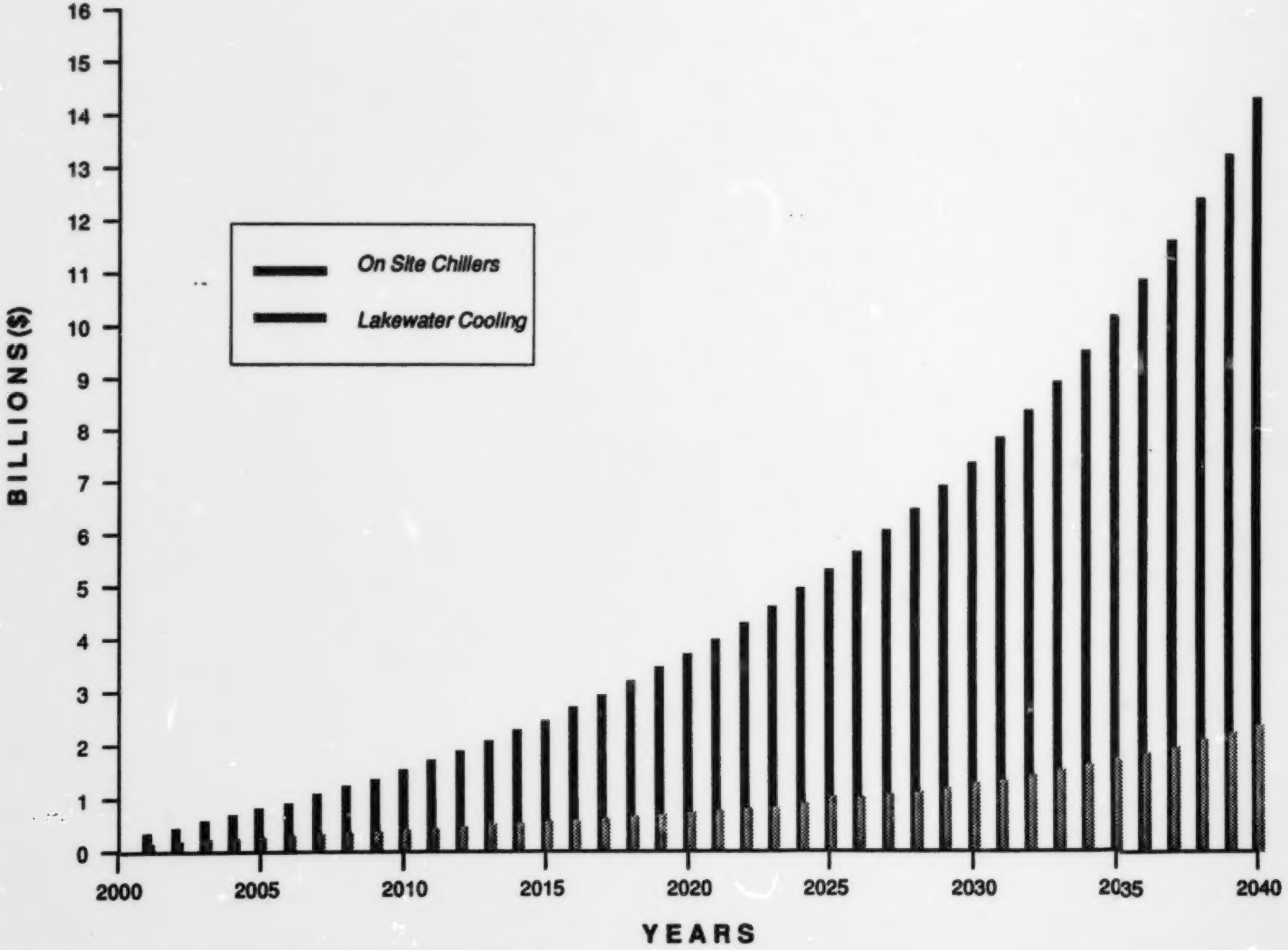


Figure 49

Sensitivity to Lakewater Cost

Alternate Scenarios

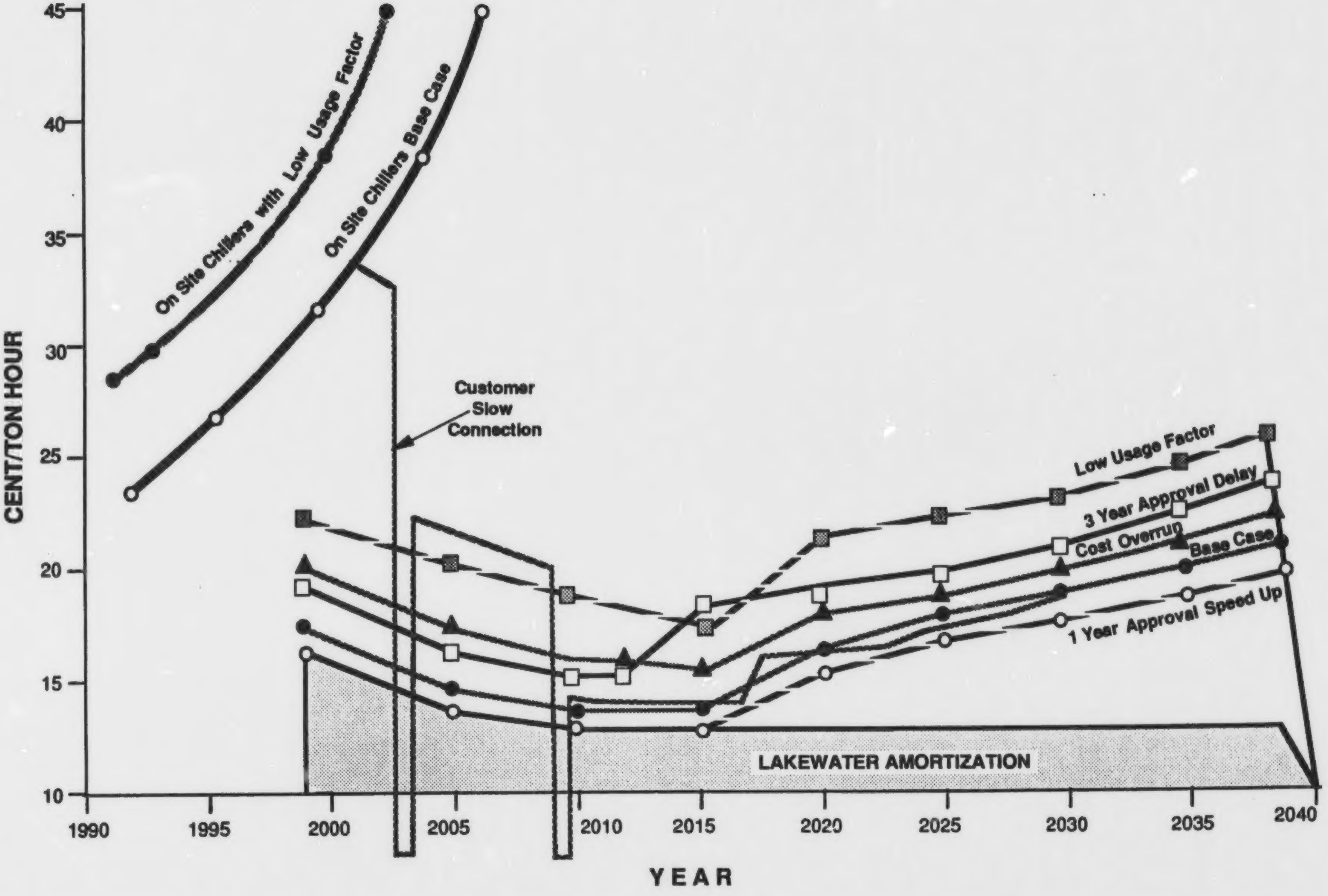
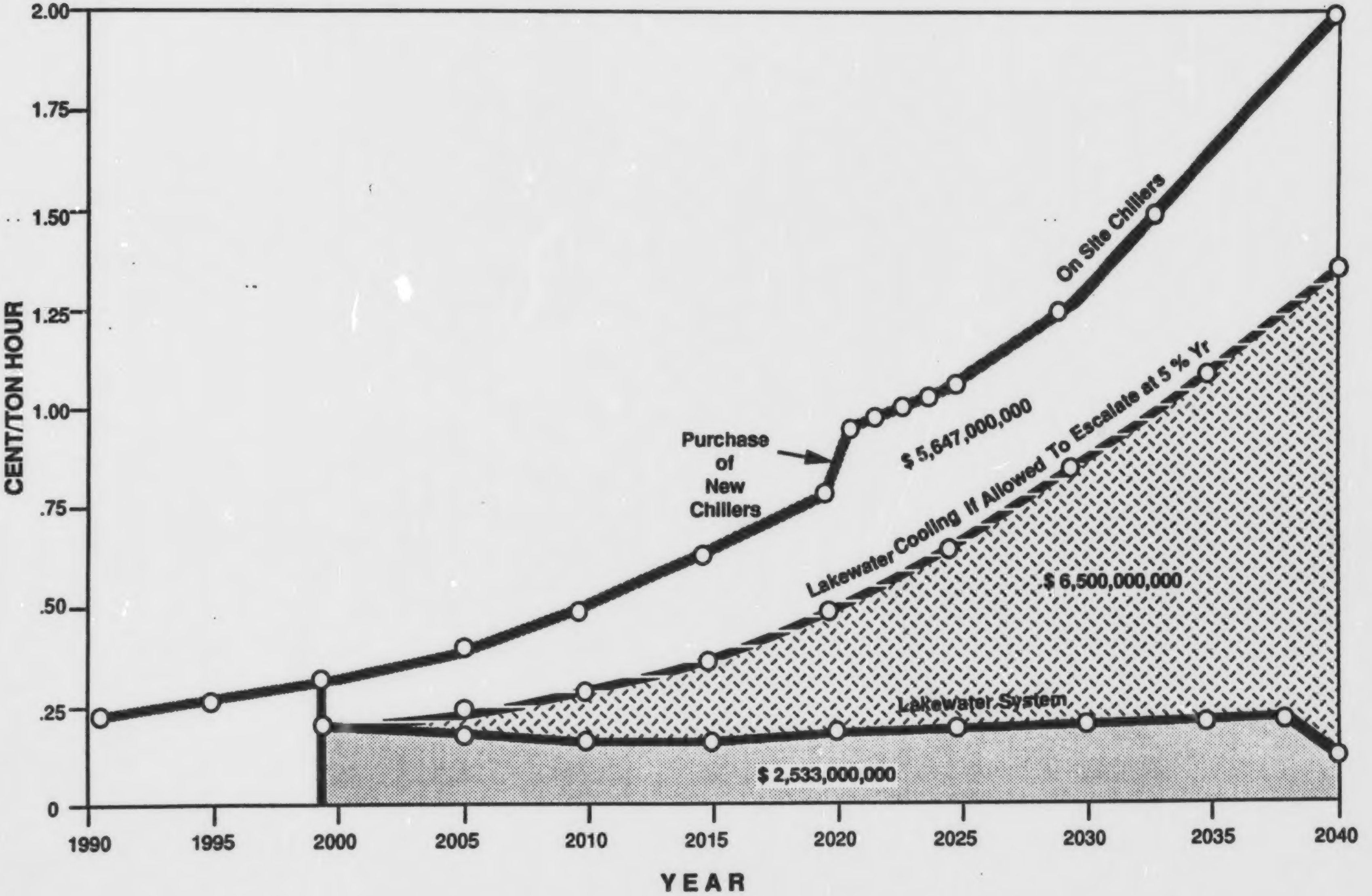


Figure 50

Income Potential for Lakerwater System



APPENDIX A

Letter from Dr. Farrell Boyce
National Water Research Institute

RECEIVED
APR 12 1991

National Water Research Institute
867 Lakeshore Road, P.O. Box 5050
Burlington, Ontario, L 7 R 4 A 6
April 9, 1991

Mr. Robert Tamblyn
Energy Interface
2 Sheppard Avenue East, Suite 200
Willowdale, Ontario, M2N 5Y1

Subject: Drawdown of Lake Ontario Thermocline Due to Cold Water Withdrawal for the FREECOOL System

Dear Mr. Tamblyn:

In your recent conversation you told me that the projected withdrawal of cold water from Lake was 36 x 10^9 US gallons per year (264 US Gallons = 1 m^3). You asked me if this withdrawal would have any significant effect on the temperature distribution of Lake Ontario as a whole.

From a chart of Lake Ontario I determined that the horizontal area of the lake at a depth of 100 m was roughly equivalent to that of a rectangle 135 nautical miles (1 nautical mile = 1.852 km) long by 20 nautical miles wide, that is to say 9260 km^2. If the annual withdrawal of 36 x 10^9 gallons were taken from a layer of water centred at the 100 m depth, such a layer would be

$$\frac{36 \times 10^9 \text{ US gallons}}{264 \text{ US gallons/m}^3 \times 9260 \text{ km}^2 \times 10^6 \text{ m}^2/\text{km}^2} = 0.015 \text{ m thick}$$

On a lakewide basis, this is a very small fraction of the observed year-to-year variation in a reference depth such as the depth of the 10°C isotherm at the time of maximum heat content. If you were to increase the withdrawal by a factor of 50 you might then wonder about the overall impact.

It is possible that selective withdrawal of water from the weakly stratified zone below the thermocline could produce local modification of the thermal structure. In our earlier paper (Boyce *et al.* 1983. Atmosphere-Ocean 21 (4): 397-417) we discussed an extreme and pathological example involving swirling flow that could easily be avoided by intake design. It is my *view* that in the dynamic Lake Ontario environment, local modification of the thermal structure would be undetectable more than 1 km away from the intake. Supporting computations could be undertaken but they would be costly.

Yours sincerely,

Farrell Boyce
Lakes Research Branch
National Water Research Institute

APPENDIX B

Report from Proctor & Redfern Limited

ENGINEERING INTERFACE LIMITED

REPORT ON CIVIL ENGINEERING WORKS FOR DOWNTOWN TORONTO DEEP LAKE WATER COOLING SYSTEM

Prepared by

PROCTOR & REDFERN LIMITED
45 Green Belt Drive
Don Mills, Ontario
M3C 3K3

E.O. 91115

APRIL 1991

APPENDIX B

PROCTOR & REDFERN LIMITED

April 26, 1991

Project E.O. 91115

Mr. Robert Tamblyn, P. Eng.
Chairman
Engineering Interface Limited
2 Sheppard Avenue East
Suite 200
Toronto, Ontario
M2N 5Y7

Dear Bob

Re Downtown Toronto Deep Lake Water Cooling System

We are pleased to enclose herewith six (6) copies of our Report on the Civil Engineering Works for the above project.

We look forward to meeting with you and the parties involved in reviewing the proposed scheme. We will also be pleased to take part in the Charrette which commences on Sunday, June 16, 1991.

It is our sincere hope that the project proceeds to the next phase, and we look forward to continuing our work with you.

Yours very truly

Proctor & Redfern Limited

Rod Holme

Rod Holme, P. Eng.
Manager, Water and Wastewater

RH:mv

c Mr. R.V. Honsberger, P.Eng.
MacViro Consultants Inc.

EE:\WATER\RPT1\91115LTR

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Appendix A	Report by Jason Consultants SA on Installation of Supply and Return Pipes by Trenchless Technology

1.0 INTRODUCTION

The "Freecool" concept of using cold water from an 80 m depth of Lake Ontario as a substitute for water which is cooled by electrically driven chillers was previously investigated in 1980. Proctor and Redfern took part in that investigation, and reported on the civil engineering works for a downtown Toronto cooling plant, to provide an operational flow from Lake Ontario of up to 12.6 m^3/s (200,000 US gpm).

This current report details the results of a preliminary investigation of the required civil engineering works for a cooling system that extends over a far larger area of downtown Toronto. The area runs generally from Lake Ontario up to Bloor Street, and is centered on Yonge Street and University Avenue. The operational flow has been increased to 37.8 m^3/s (600,000 US gpm). The works necessary to increase the capacity of the intake to 75.7 m^3/s (1,200,000 US gpm) have also been considered.

The scheme involves taking cool water from a depth of 80 m in Lake Ontario through an intake crib. The water is conveyed to the shore through a tunnel which is approximately 6 km long. At the harbourfront, pumps are used to deliver the water to the downtown Toronto area by means of tunnels constructed in a northerly direction up to Bloor Street. A series of east-west connections transmit the water from the tunnels to the downtown buildings for cooling purposes.

The return water is then taken back to the harbourfront via a similar collection and tunnel system. At the harbour, the energy in the return water is recovered by turbine generators, and a box culvert is used to convey the water back to the Lake.

The main civil engineering components covered by this report are the Lake intake, the supply and return tunnels below the downtown area, the main pumping and energy recovery station, and estimated costs.

2.0 LAKE INTAKE TUNNEL

The purpose of the intake tunnel is to convey water from an 80 m depth in Lake Ontario to the pumping station.

2.1 Intake Route

Two potential routes for the intake tunnel were examined. The first was a direct route, Number 1, from the nearest location of 80 m deep water, with a pumping station sited on land next to the Yonge Street Slip. The second was an indirect route, Number 2, from an alternative point of 80 m deep water, with a pumping station sited to the east of the Eastern Gap. Both of these routes are shown in Figure 1.

2.2 Intake Type

Three types of intake were considered; firstly, a tunnel for the whole length; secondly, a pipe laid in an excavated trench on the lake bed for part of the length and a tunnel for the remainder; and finally, a pipe laid in an excavated trench on the lake bed for the whole length.

Because of practical and economic reasons, the tunnel for the whole length is considered to be the most viable option. A tunnel would cause the minimum disturbance in the harbour, the lake and on the Islands. Furthermore, the high labour and material disposal costs associated with working on the Islands would be avoided. The difficulties of divers working and laying a pipeline in deep water would also be averted. With the tunnel constructed in rock, there would be a minimum temperature gain to the cool water taken from the lake.

For a pipeline constructed from the surface in the harbour and in shallow water in the lake, the pipe would have to be laid in an excavated trench, so that it was below the bed of the lake. This method of construction would cause maximum disturbance. Additionally, with the size of the pipe required, up to 5.5 m in diameter, the trench in the harbour is likely to be partly in rock. Also, working from the Islands would attract high labour and material disposal costs.

For the part tunnel option the transition from surface construction to tunnel would be expensive. Generally the longer a tunnel is, the more economical it becomes, because of the high setup costs for the tunnelling machine and access shaft. Therefore, if tunnelling is being considered, it should be for the whole length.

Finally for the surface construction for the total length, the section of pipelaying in 80 m of water will be slow and expensive, because of the difficulties of divers working in deep water.

2.3 Tunnel Construction

The tunnel would be constructed in the Dundas Shale, which is a relatively soft rock, and is a good tunnelling material. The depth of rock required above a tunnel is normally three times the excavated diameter, and would therefore be approximately 15 m for the intake.

Contractors prefer that the slope of the tunnel is away from the excavation face to ensure that water seepage is conveyed away from the face. The main reason for this method of excavation is to reduce the risk of the tunnelling machine being submerged, since these machines cost between $2 and $3 million. A slope of one tenth of one degree is sufficient.

With a water depth of 80 m at the intake and 15 m of rock cover over the tunnel, a reverse slope would produce a shaft depth at the Yonge Street Slip of 104 m. A final decision regarding the tunnel slope can be made at a later date, because the cost difference is not likely to be very significant in the overall study. Figure 2 shows the tunnel in section.

Finally, for up to three months after excavation, the phenomenon of rock squeeze takes place, and it will be necessary to verify its significance for this particular tunnel.

2.4 Hydraulic and Financial Analysis

For the maximum flow of 37.8 m^3/s (600,000 US gpm) a range of tunnel sizes was appraised for both Routes 1 and 2. The internal friction loss was assessed using a "C" factor of 120. Tunnelling costs were estimated with reference to recent tunnelling projects and discussions with Contractors, and current Toronto Hydro rates were used for energy costs.

The tunnel length for Route 1 is 5945 m, and for Route 2 is 7010 m. Four tunnel diameters were considered, ranging from 3.66 m to 4.75 m. The corresponding velocities ranged from 3.6 m/s to 2.1 m/s, and the resulting head losses varied from 2.29 to 0.64 m per 1000 m. The estimated costs given in Section 11 of this report are based on Route 1.

The most economic tunnel size for a flow of 37.8 m^3/s (600,000 US gpm) is 4.27 m. This tunnel gives a velocity of flow of 2.65 m/s and a head loss of 1.08 m per 1000 m.

If it were decided to construct an intake capable of providing a flow rate of 75.7 m^3/s (1,200,000 US gpm) then a 5.65 m diameter tunnel would be required. In this case the velocity would be 3.0 m/s, and the resulting head loss 1.02 m per 1000 m.

For both of these tunnel sizes, the drawdown at maximum flow will be approximately 6 to 7 m. Taking a lake level of 75.0 m, the minimum onshore pumping station well level will therefore be in the range of 68.0 to 69.0 m.

3.0 LAKE INTAKE CRIB

The intake crib would be located on or near the bottom of the lake, and it would be used to draw water into the intake tunnel.

3.1 Design Requirements

The main requirements of the intake structure would be to achieve as near horizontal a flow from the lake as possible, to minimize the draw down of warmer water from above. The intake must also be designed to minimize the entrapment of fish into the intake tunnel.

The velocity at the crib surface would be required to be in the 150 mm to 300 mm per sec range, and it would need to be designed to provide smooth acceleration into the intake tunnel.

3.2 Type of Intake Crib

The flow into the intake could be either horizontal through a vertical face, or downward through a horizontal surface. For a velocity of 150 mm per sec, a vertical circular intake would be approximately 28 m in diameter, and have a vertical height around the perimeter of 3 m. The individual vertical area of flow would be 150 mm by 3 m.

A circular downward flow intake, for a velocity of 150 mm per sec, would be approximately 21 m in diameter with a central 8 m diameter core without flow. Both intakes are shown diagrammatically in Figure 3.

There are numerous alternatives to these two designs, and an important factor for investigation at the next stage of the study will be the method of construction at an 80 m depth.

4.0 SUPPLY AND RETURN TUNNELS

The supply and return tunnels are required to deliver water to the downtown area for cooling purposes, and collect the return water for energy recovery and discharge back into the lake.

4.1 Tunnel Type

The supply and return tunnels could be constructed individually , or as a single, larger tunnel with a central dividing wall to separate the supply and return flows. The cost for a single tunnel would be considerably in excess of individual tunnels, because of the cost of the dividing wall, which would have to be designed to withstand large pressure differences between the supply and return sides. A steel membrane is also likely to be required, along with thermal insulation. A reinforced concrete dividing wall would need to be up to 1 m thick.

Separate supply and return tunnels are therefore recommended.

4.2 Tunnel Route

The most desirable location for the supply and return tunnels to facilitate flow distribution to and from the downtown buildings, would be under Yonge Street and University Avenue. The tunnels would be constructed below the level of the subways, service conduits and pipes. If these routes prove to be too congested, other streets which run in parallel with Yonge Street and University Avenue are available. The construction of individual flow and return pipes greatly facilitates the potential of other routes. A decision on the precise route need not be taken at this stage, and the eventual location will not significantly affect the final cost of the project.

4.3 Tunnel Construction

The tunnel could be constructed either deep in rock or relatively shallow in the clays and sands below all underground services. The tunnels must be in one material or the other, because mixed tunnelling between rock and soils is not practical. For the shallower tunnel, groundwater is present at a depth of approximately 5 m below the ground surface. Tunnelling in the rock is likely to be simpler and less expensive, but the vertical supply shafts will be relatively deep, up to 50 m at Bloor Street.

It is anticipated that the vertical supply pipes from the tunnel would be drilled from the surface, and a watertight seal made between the pipe and the tunnel. The supply and return pipes to the buildings, which would be in the 300 to 1000 mm diameter range, could be constructed by trenchless technology from the same surface locations as the vertical risers.

The supply and return tunnels will operate at pressures of up to 70 m.

4.4 Hydraulic and Financial Analysis

For the maximum flow of 37.8 m^3/s (600,000 US gpm) a range of tunnel sizes was appraised. The flow decreases progressively as water is supplied to the buildings, and the size of the tunnel could therefore be reduced. The analysis was therefore completed in two sections, between the main pumping station and Queen Street, and between Queen Street and Bloor Street.

Three tunnel diameters were considered for each section, and the diameters ranged from 1.8 m to 3.35 m. The velocities ranged from 3.2 m/s to 1.7 m/s, and the resulting head losses varied from 3.59 to 0.88 m per 1000 m.

The most economic tunnel sizing for a total flow of 37.8 m^3/s (600,000 US gpm) is 3.0 m between the main pumping station at Queen Street, and 2.1 m between Queen Street at Bloor Street. Under Yonge Street there would be a flow and a return tunnel. There would also be a flow and return tunnel under University Avenue. The total individual tunnel distance between the main pumping station and Bloor Street is 3900 m.

5.0 SUPPLY AND RETURN PIPES (TRENCHLESS TECHNOLOGY)

The purpose of the supply and return pipes is to transmit water between the underground tunnels and the buildings.

The initial concept was to locate the pipes in the basements of the downtown buildings. However, it would be worth considering the alternative of constructing the pipe underground by trenchless technology. Proctor & Redfern have therefore arranged for Jason Consultants SA to prepare a preliminary report which describes the options available, and their associated approximate cost. This report is attached as Appendix A.

5.1 Alternative Methods of Design

Three potential trenchless methods have been proposed by Jason Consultants SA. Firstly, Alternative A is to construct a reinforced concrete carrier pipe by pipe jacking, and draw the flow and return pipes through the carrier pipe. Secondly, Alternative B is to again construct a reinforced concrete carrier pipe, but only install a flow pipe, with the annular space being used for the return flow. And finally, Alternative C is to adopt a different approach, and use guided boring technology and pull the supply and return pipes behind the boring equipment.

The construction costs for approximately 23,000 m of supply and return pipe would be $53 million for Alternative A, $44 million for Alternative B, and $31 million for Alternative C. The detailed breakdown of the cost per metre for each of the alternatives is given in Appendix A. These costs have not been included in the estimates given in Section 11 of this report.

6.0 MAIN PUMPING and ENERGY RECOVERY STATION

Water from the lake would need to be pumped to the downtown area. When the water returns to the pumping station, some of the pumping energy would be unused, and this energy could be recovered. After the energy has been recovered by turbine generators, the water would be returned to the lake through an outfall box culvert.

6.1 Location

It has been assumed that pumping and energy recovery would take place at the same site. The station should be located at the edge of the lake, as near to the downtown area as possible. A specific site has been identified to the east of the Yonge Street Slip, and the station has been arranged to fit in the southeast corner of this site, next to Redpath Sugar.

Because of the size of the area available, and the requirement to minimize the structure above grade (which is likely to be valid for other locations), the main pumphouse only has been designed to be above grade, with the energy recovery station, electricity substation, and outfall, all located below grade. Figure 4 shows a plan view of this arrangement.

6.2 Main Pumping Station

The general arrangement of the pumping station is shown in Figure 5. The vertical turbine pumps would be positioned at approximately 3.3 m centers around the perimeter of a circular 20 m diameter wet well. The pump impeller would be positioned below the water surface, and be driven through vertical drive shafts attached to motors located in the main pump room. The pumps would deliver into a circular discharge pipe, which would in turn convey the water to the supply tunnel via a vertical discharge pipe.

An overflow weir arrangement would be constructed around the perimeter of the wet well to dissipate overflow water during surge conditions. This water would be conveyed to the outfall culvert. Any surge associated with the supply tunnels would be dissipated by horizontal surge vessels located alongside the circular discharge pipe.

The electrical panels associated with the pumping equipment will be located on the pump room floor. Also a screening arrangement would be required on the vertical intake shaft, with an isolating valve as shown. Suitable valves and pipework to drain down the supply and return tunnels could be provided at the pumping station.

The circular pumping station building would be 42 m in diameter, with a height of approximately 16 m above a grade level of 77.7 m.

6.3 Turbine Gallery

The return water would be fed from the tunnel through a vertical pipe into a delivery main running in parallel with the lake shoreline as shown in Figure 4, and the section in Figure 6. Energy would be recovered by turbines, which would in turn discharge into the outfall culvert for return to the lake. The turbine gallery would be below grade, and contain the necessary electrical equipment.

6.4 Outfall

A large box culvert would carry up to 37.8 m^3/s (600,000 US gpm) of return water back into the harbour. Based on a velocity of 150 mm/s, the culvert would be 5.5 m long by 4.5 m high by 3.0 m wide. It would be constructed along the harbour wall, and the top of the culvert would be 2.3 m below the harbour water level. An internal baffle arrangement would be required to evenly distribute the turbine discharge water to the lake.

6.5 Electrical Substation

An electrical substation would be constructed below grade, next to the turbine gallery, as shown in Figure 4. The substation would receive primary power at 13.8 kv from two separate feeders. The total energy requirement of the pumps is 32 MVA, and therefore three 11 MVA transformers would be required. With an energy recovery of 9 MW, two transformers would normally be in operation, with one acting as standby.

7.0 PUMP SELECTION

7.1 Pump Type

For the large flow and relatively high heads, vertical turbine pumps are recommended. Vertical turbines are versatile because additional stages can be added for more head. They are well proven pumps and the overall efficiency, wire to water, should be at least 80 percent.

7.2 Pump Duty

From the longitudinal section shown in Figure 2, it can be seen that a pump delivery head of 137 m is required. This is based on a suction head of 68.5 m as described in Section 2.4, and a residual pressure of 15.2 m at grade of 115.8 m at Bloor Street. This pressure is required to overcome losses in the supply and return pipework system and the heat exchangers. Therefore the pump rated head is 68.6 m at the maximum flow rate of 37.8 m^3/sec (600,000 US gpm).

A practical maximum pump capacity for this rated head is 3.15 m^3/s (50,000 US gpm), and therefore twelve 3,500 HP units would be required. For operational and control purposes, a combination of variable speed and fixed speed units would be used. Space has been provided for sixteen pumps, to include standby provision. The total horsepower rating of the motors would be 42,000 HP.

8.0 SURGE PROTECTION

On power failure, surge conditions will exist both in the intake tunnel, and the supply tunnel.

8.1 Intake Tunnel Surge

The intake tunnel surge can be dissipated by allowing an overflow at the main pumping station into the outfall box culvert.

8.2 Supply Tunnel Surge

An initial computer analysis has been completed for the supply tunnels at a maximum flow rate of 18.9 m^3/s (300,000 US gpm) along each tunnel. The hydraulic system is relatively short for such large diameter pipes, and the surge wave is reflected back quickly, resulting in higher surge values. The worst surge occurs at the change in tunnel size at Queen Street. Surge vessels are therefore likely to be required. One vessel would be needed for each of the two supply tunnels, and the size of each would likely be approximately 4 m in diameter and 15 m long.

9.0 ENERGY RECOVERY

When the water returns to the lake, there is energy available for recovery.

9.1 Turbines

It can be seen by reference to Figure 2, that the total return head available for recovery at the main pumping station is 109.7 m at the maximum flow rate of 37.8 m^3/s (600,000 US gpm). The water is to be returned to the Lake at 75.0 m level, and the head available for recovery is therefore 30.5 to 33.5 m.

Four turbines could be used to recover this energy prior to discharge, back into the lake. It would also be necessary to provide backup flow control valves to dissipate the energy of the returning water in the event of the turbines being out of operation.

9.2 Energy Recovered

The overall water to wire efficiency of the turbines would be approximately 80%. Therefore approximately 9,000 kw or 12,000 HP can be recovered. Each turbine would therefore be 3,000 KW capacity. When comparing the input power of 42,000 HP, this represents a 29 percent recovery of input power.

10.0 EXCAVATED MATERIAL DISPOSAL

The material excavated from the tunnels would need to be disposed of.

10.1 Excavated Volume

Approximately 250,000 cubic meters of material would be excavated from the tunnels. This volume is based on a 4.27 m diameter intake tunnel along the direct Route 1, and 3.0 m and 2.1 m individual supply and return tunnels.

The material will be Toronto shale for the intake (115,000 cu. m), and will vary for the supply and return tunnels depending on the route and depth chosen.

10.2 Disposal Site

This material could be disposed of at the Leslie Street Spit, or as clean fill on downtown redevelopment sites.

11.0 ESTIMATED COSTS

The following are the estimated costs are for the construction of the works.

		$ Millions
Intake Tunnel		
	From Intake Crib to Pumping Station, Route 1 4.27 m dia., total length 5,950 m at $5,100 per m	30.3
Supply and Return Tunnel		
a)	From Pumping Station to Queen Street 3.0 m dia., total length 8,400 m at $3,600 per m	30.2
b)	From Queen Street to Bloor Street 2.1 m dia., total length 7,200 m at $2,900 per m	20.9
Vertical Shafts to Supply and Return Tunnels		4.0
Pumping and Energy Recovery Station		
a)	Building, below ground structure and outfall box culvert	14.3
b)	Pumps, turbines, electrical switchgear, electricity substation, surge vessels, valves and screen	14.7
Intake Structure		3.5
TOTAL CONSTRUCTION COST		117.9
Engineering and Contingency (20%)		23.6

For an intake tunnel with twice the capacity, for a flow rate of 75.7 m^3/s (1,200,000 USgpm), the estimated cost for a 5.65 m dia. tunnel along Route 1, at $8,900 per m, is $53.0 million.

These estimates are based on 1991 construction costs. The cost of the tunnelling very much depends on the rock and soil conditions, and estimates could change once a detailed subsurface investigation is complete.

12.0 SUMMARY

This report outlines the preliminary sizing and layout of the civil engineering works and plant. The recommendations contained should be evaluated in detail as part of the next stage of the study. Should you require additional details on any matter contained in the report, please do not hesitate to contact Proctor & Redfern Limited.

Report Prepared by:

Kingsley Blease, M.I.C.E.
Geoff Cook, P. Eng.
Rod Holme, P. Eng.

April, 1991

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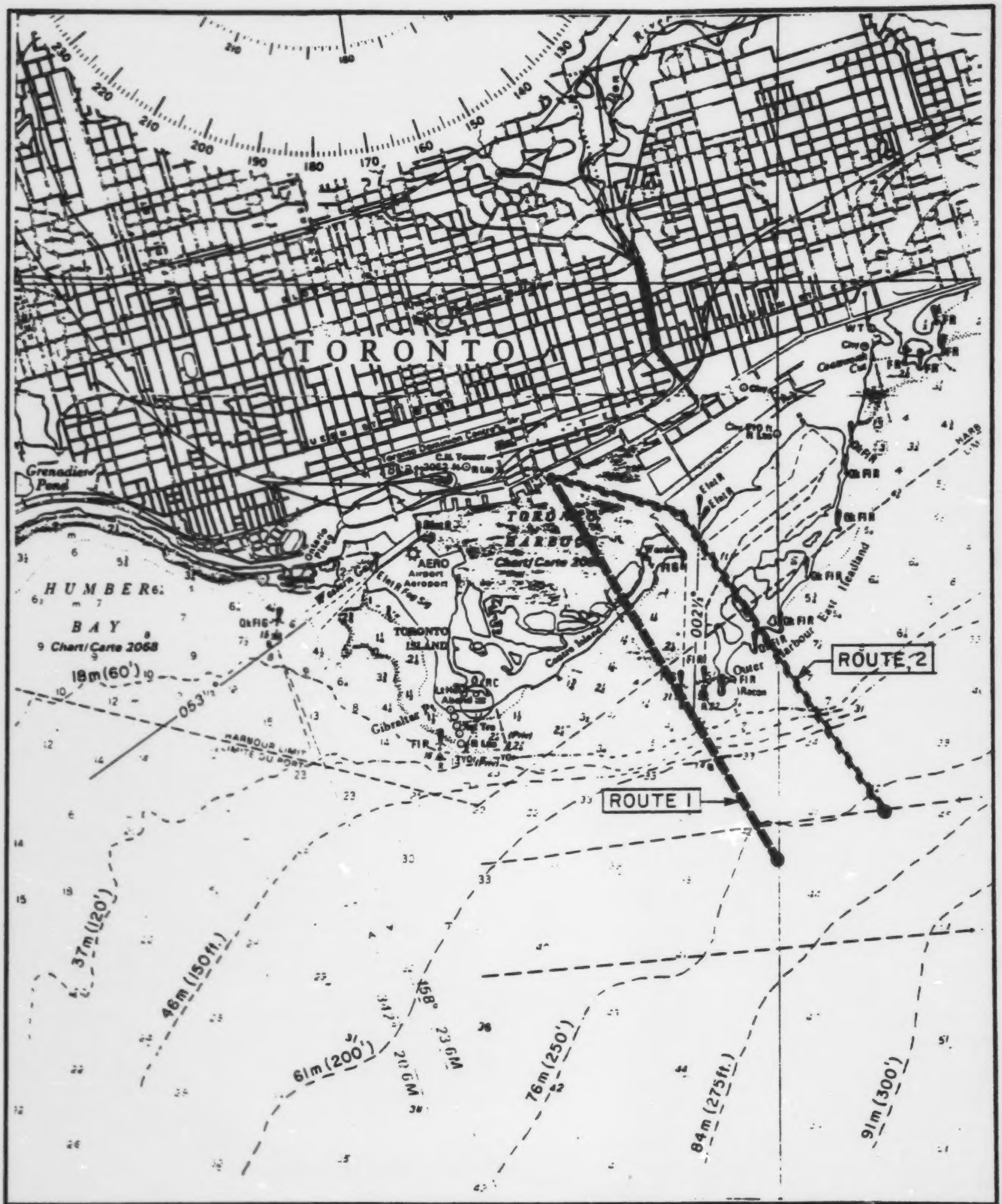

TORONTO
Don River
Grenadier Pond
C.N. Tower
Toronto Dominion Centre
TORONTO HARBOUR
Chart/Carte 2085
HUMBER BAY
Chart/Carte 2068
AERO Airport Aeroport
TORONTO ISLAND
Gibraltar Pt
Outer Harbour East Headland
HARBOUR LIMIT
LIMITE DU PORT
053°
158°
ROUTE 1
ROUTE 2
18m (60')
37m (120')
46m (150ft.)
61m (200')
76m (250')
84m (275ft.)
91m (300')
23.6M
20.6M

Drawn by

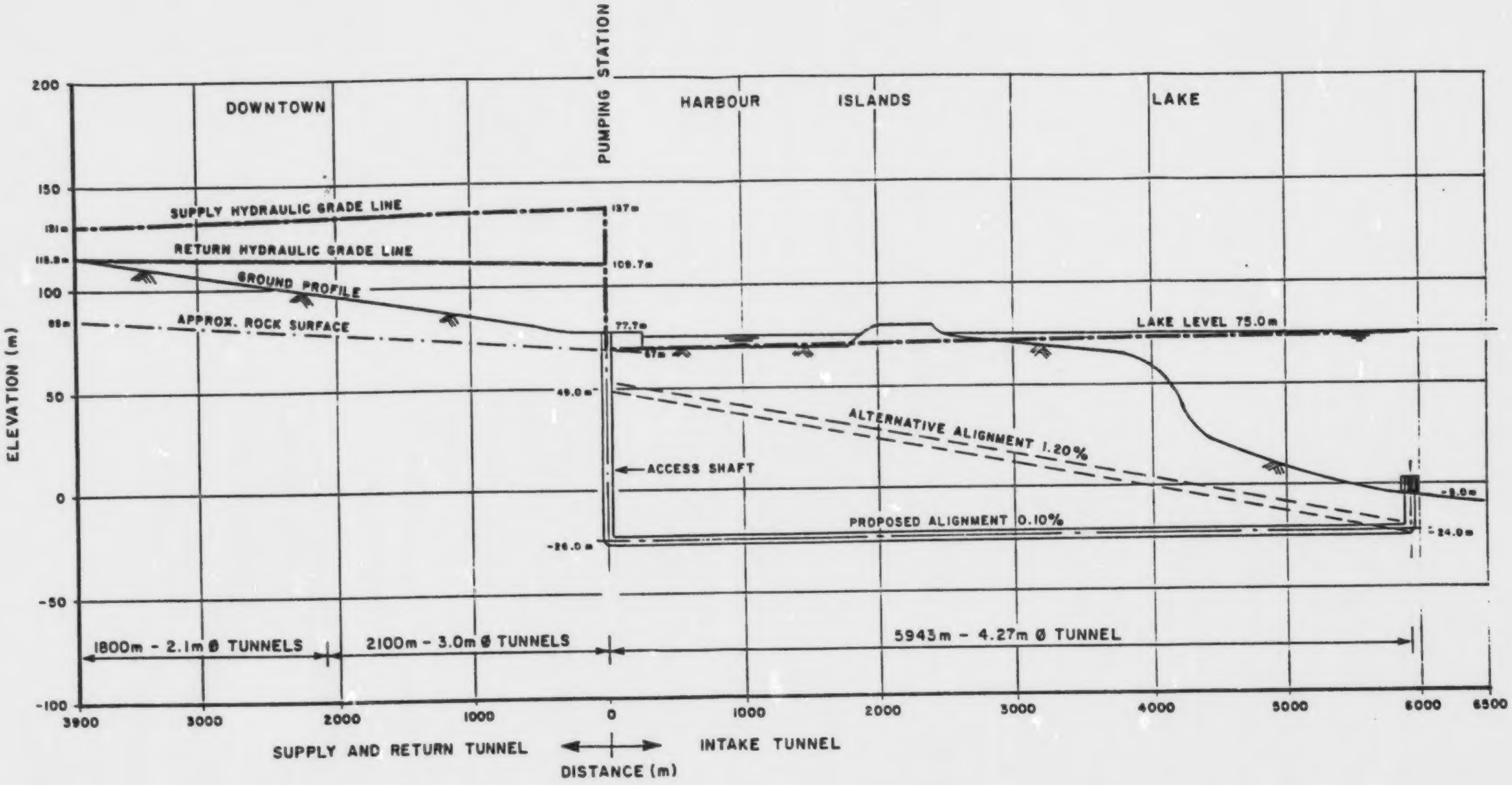
Ckd. by

DEEP LAKE WATER COOLING
DOWNTOWN TORONTO

LOCATION OF LAKE INTAKE TUNNEL

Proctor & Redfern Limited
Consulting Engineers & Architect
Toronto

Scale	Date APRIL 1991
E.O. 91115	FIGURE 1


PUMPING STATION
DOWNTOWN
HARBOUR
ISLANDS
LAKE
SUPPLY HYDRAULIC GRADE LINE
RETURN HYDRAULIC GRADE LINE
GROUND PROFILE
APPROX. ROCK SURFACE
LAKE LEVEL 75.0m
ALTERNATIVE ALIGNMENT 1.20%
PROPOSED ALIGNMENT 0.10%
ACCESS SHAFT
131m
115.8m
85m
137m
109.7m
77.7m
67m
49.0m
-26.0m
-8.0m
-24.0m
1800m - 2.1m Ø TUNNELS
2100m - 3.0m Ø TUNNELS
5943m - 4.27m Ø TUNNEL
ELEVATION (m)
200
150
100
50
0
-50
-100
3900
3000
2000
1000
0
1000
2000
3000
4000
5000
6000
6500
SUPPLY AND RETURN TUNNEL
INTAKE TUNNEL
DISTANCE (m)

DEEP LAKE WATER COOLING
DOWNTOWN TORONTO

ROUTE I - LONGITUDINAL SECTION
AT 37.8m³/s FLOW RATE.

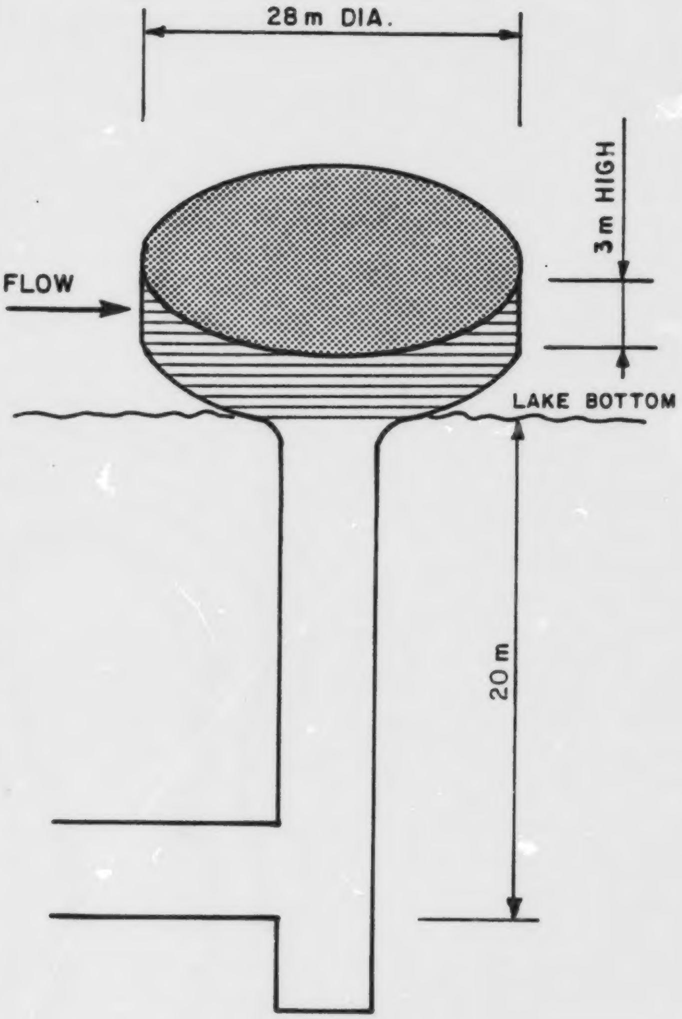
Proctor & Redfern Limited
Consulting Engineers and Architects
Toronto

Scale:
Date: APRIL 1991

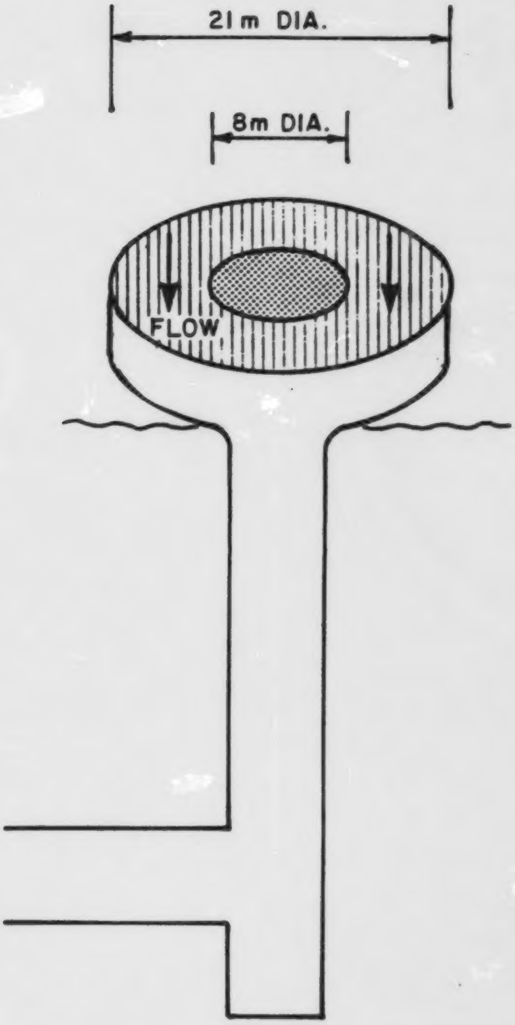
Drawn By
Chd. By

E.O. 91115

FIGURE 2

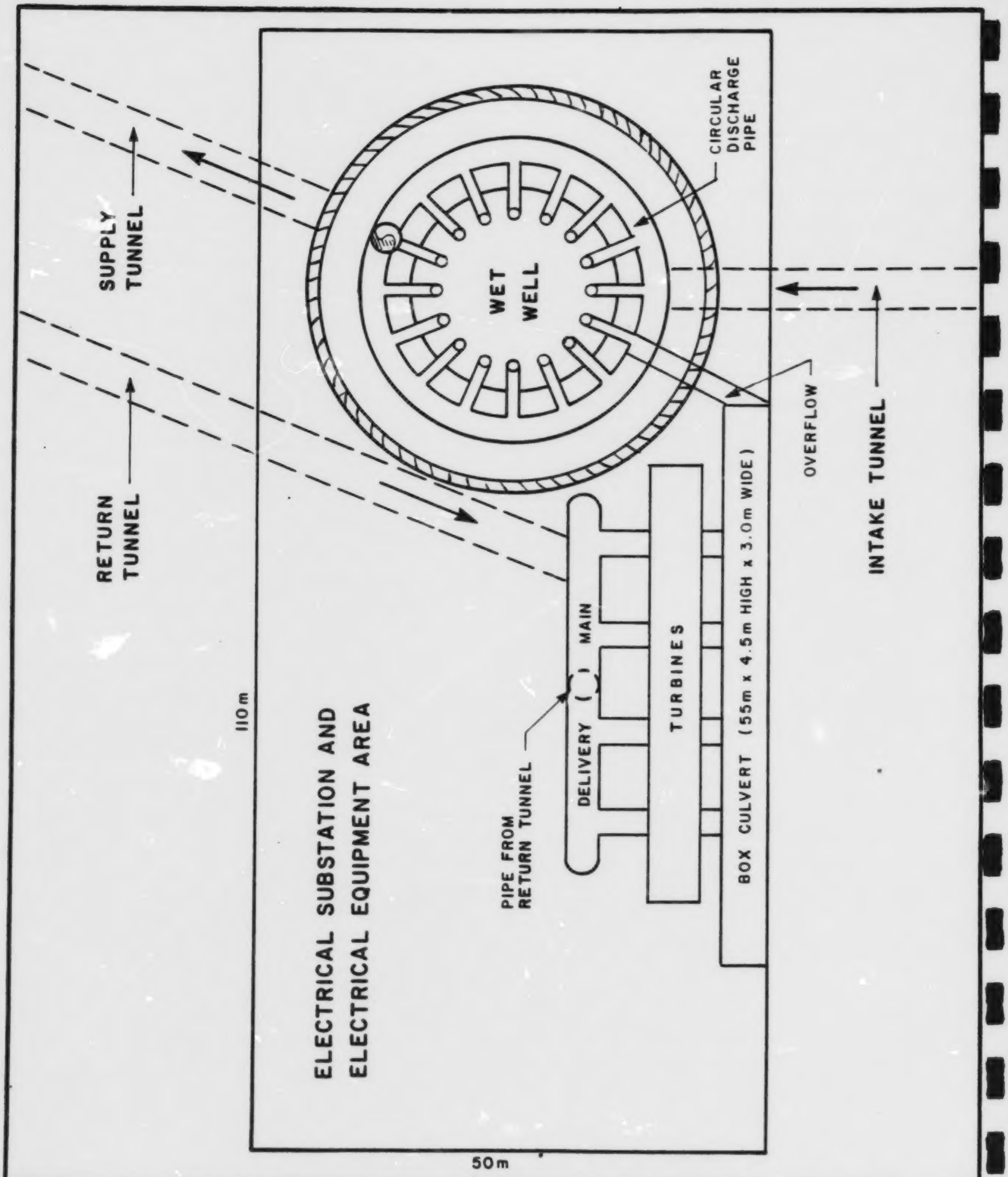

28m DIA.
3m HIGH
FLOW
LAKE BOTTOM
20 m

HORIZONTAL FLOW
VERTICAL INTAKE

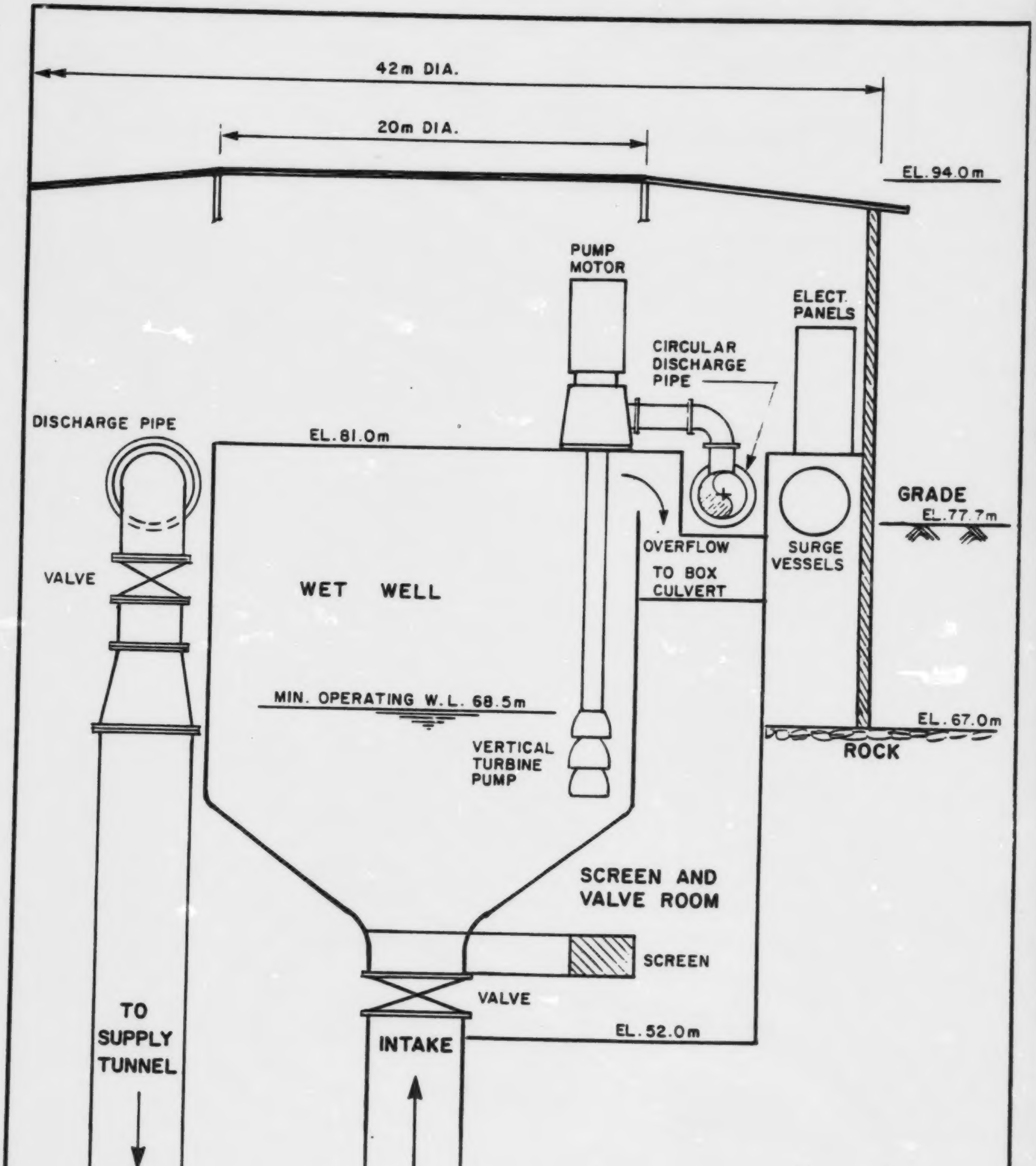

21m DIA.
8m DIA.
FLOW

DOWNWARD FLOW
HORIZONTAL INTAKE

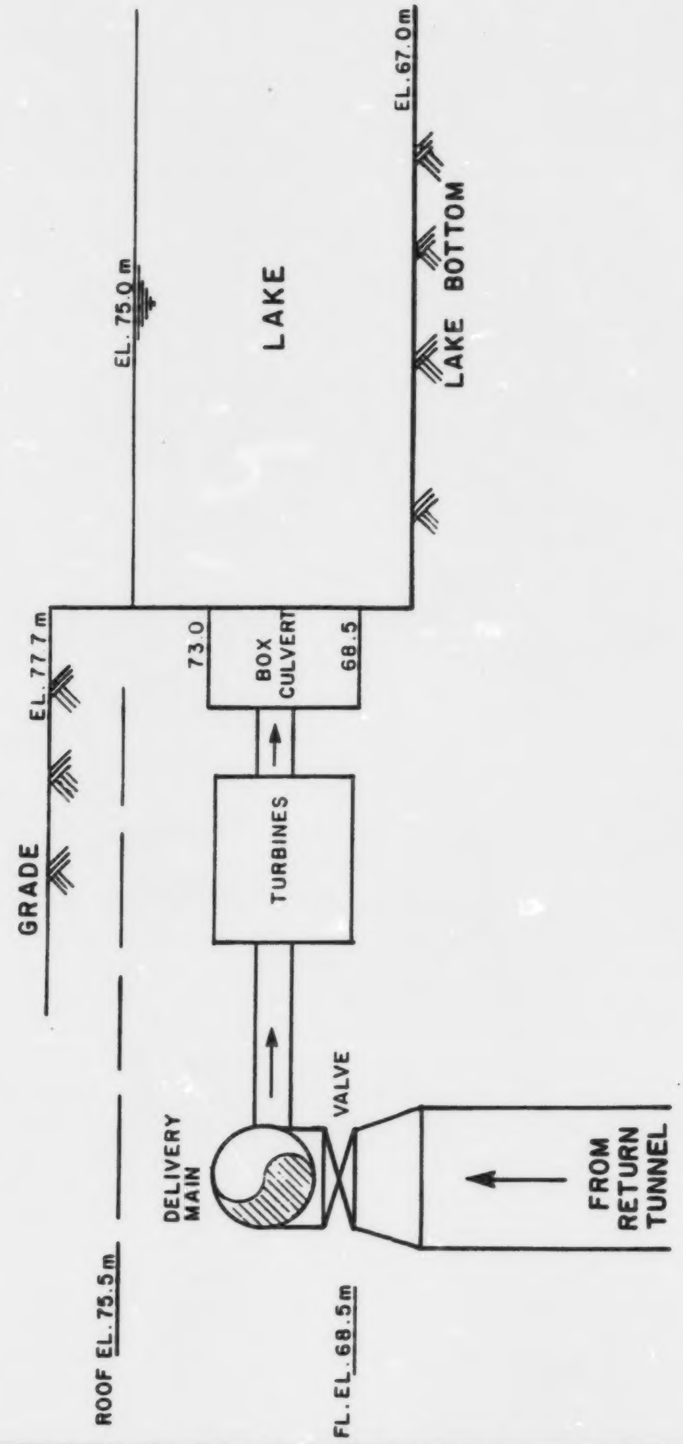
Drawn by	DEEP LAKE WATER COOLING DOWNTOWN TORONTO	Proctor & Redfern Limited Consulting Engineers & Architect Toronto	
Ckd. by	LAKE INTAKE CRIB	Scale	Date APRIL 1991
		E.O. 91115	FIGURE 3


SUPPLY TUNNEL
RETURN TUNNEL
CIRCULAR DISCHARGE PIPE
WET WELL
OVERFLOW
INTAKE TUNNEL
BOX CULVERT (55m x 4.5m HIGH x 3.0m WIDE)
TURBINES
DELIVERY MAIN
PIPE FROM RETURN TUNNEL
110m
ELECTRICAL SUBSTATION AND ELECTRICAL EQUIPMENT AREA
50m

Drawn by	DEEP LAKE WATER COOLING DOWNTOWN TORONTO	Proctor & Redfern Limited Consulting Engineers & Architect Toronto	
Ckd. by	MAIN PUMPING & ENERGY RECOVERY STATION - PLAN VIEW	Scale	Date APRIL 1991
		E.O. 91115	FIGURE 4


42m DIA.
20m DIA.
EL. 94.0 m
PUMP MOTOR
ELECT. PANELS
CIRCULAR DISCHARGE PIPE
DISCHARGE PIPE
EL. 81.0m
GRADE
EL. 77.7m
OVERFLOW TO BOX CULVERT
SURGE VESSELS
VALVE
WET WELL
MIN. OPERATING W. L. 68.5m
EL. 67.0m
ROCK
VERTICAL TURBINE PUMP
SCREEN AND VALVE ROOM
SCREEN
VALVE
TO SUPPLY TUNNEL
INTAKE
EL. 52.0m

Drawn by	DEEP LAKE WATER COOLING DOWNTOWN TORONTO	Proctor & Redfern Limited Consulting Engineers & Architect Toronto
Ckd. by	MAIN PUMPING STATION ELEVATION	Scale — Date APRIL 1991 E. O. 91115 — FIGURE 5


EL. 67.0m
LAKE BOTTOM
LAKE
EL. 75.0 m
EL. 77.7 m
GRADE
73.0
BOX CULVERT
68.5
TURBINES
VALVE
DELIVERY MAIN
FROM RETURN TUNNEL
ROOF EL. 75.5m
FL. EL. 68.5m

Drawn by	DEEP LAKE WATER COOLING DOWNTOWN TORONTO	Proctor & Redfern Limited Consulting Engineers & Architect Toronto	
Ckd. by	ENERGY RECOVERY GALLERY INCLUDING OUTFALL BOX CULVERT	Scale	Date APRIL 1991
		E.O. 91115	FIGURE 6

APPENDIX A

Jason Consultants SA

FREECOOL PROJECT - TORONTO

REPORT ON INSTALLATION OF BRANCH LINES

INTRODUCTION

At the request of Proctor and Redfern we have undertaken an overall technical and economic review of the installation by "trenchless methods" of the flow and return branch lines on this project.

These branch lines, which will serve the properties along each side of the street, run at right angles to the main feeder lines located in University and Yonge. The feeders are in 12", 18" and 24" internal diameter. In addition a length of 36" diameter is shown on railway lands.

To undertake this work by traditional open cut trenching would be extremely disruptive to business and the community. It would also cause damage to pavements, existing pipes and cables and possibly adjacent structures. It would also be dirty and environmentally unfriendly.

ASSUMPTIONS

Installation

We have assumed that in order to withstand the working head of 60 metres steel pipes with welded joints will be used. This is proven technology and allows for introduction of connections, tees, valves and so on using standard practice.

We have assumed that along each street it will be necessary to install a flow and return line each of the same size. In Alternative B we have assumed that the return will be at a lower head.

We have for each alternative assumed that the flow line will be an insulated pipe of the type used in district heating schemes and that the return line will be a standard steel pipe with external and internal corrosion protection. Table 1 provides our basic cost assumptions for provision of pipe, protection and also cost of installation including all welding of joints and making good insulation, protection etc.

Building Connections to Feeder Lines

We would strongly recommend that the practice of installing right angled lateral connections direct on to the feeder lines be discouraged. We would propose that the working shafts be converted into permanent access points and all connections to be made only to these manholes. We show in Sketch 1 a typical layout we have in mind. We have not costed these connections in this exercise but by use of trenchless boring methods the costs should be directly competitive and also greatly reduce damage and disruption.

Depth of Construction

We have assumed a typical depth of construction of 4 metres. At this depth the conflict with pressure pipes and cables should be negligible and the main concern will be in locating the lines to avoid the existing sewer network. It should be noted that there is hardly any cost penalty in using trenchless methods for varying this depth to say 5 metres if this is thought preferable.

Ground Conditions

We have noted the Golder Associates letter of April 18th and that the branch lines will be located in silty clay till deposits with significant sand layers. We have also noted from Tables 1 and 2 the expected bedrock depth. At our proposed depth of installation we have not allowed for working in this bedrock. We also note the anticipated water table levels and, that at the chosen depth of construction, we may be sometimes working up to 1500mm below the table. We have proposed methods of working which are not vulnerable to working at these kind of depths below the water table. We do not anticipate that there will be any necessity to undertake any dewatering of the line although some pumping may be required at working shafts.

Costing Assumptions

Our budget prices are current costs quoted in Canadian dollars.

The budget costs are the site cost of work including contractors profit and overhead plus a 10% contingency. They do not include engineering and supervision costs, diversion of existing pipes and cables, city costs, taxes etc.

ALTERNATIVE METHODS OF DESIGN

Alternative A

In alternative A we have proposed a carrier pipe which will contain the flow and return pipes. See Sketch 2.

The carrier pipe will be a reinforced concrete pipe with a sealed spigot type joint installed by pipe jacking. Length of drives will be about 200 metres with drive and reception pits located at the least disruptive positions.
The drive and reception pits will be converted into permanent access points for making and maintaining building connections.

The carrier pipe after installation will be provided with a concrete bed and the branch pipes will be drawn into the carrier on rollers and located internally by use of spacers. It is not thought to be necessary to fill the annular space as this will provide the opportunity for future replacement by drawing the pipes. It could also provide a useful and valuable access for other pipes and cables.

We propose the following carrier dimensions but these could be varied.

24" lines	60" Carrier
18" lines	48" Carrier
12" lines	42" Carrier

Budget Costs

Our budget costs for Alternative A form of construction are:

24" lines

Provision and installation of 60" carrier pipe including costs of shafts and conversion to chambers Price per metre	$1400
Provision of concrete bed, rollers and spacers Price per metre	$150
Cost of provision of branch pipes	
24" Non-insulated per metre	$160
24" insulated per metre	$300
Cost of installation, including jointing, and corrosion coating	
24" Non-insulated per metre	$170
24" insulated per metre	$300
Sub-total	$2480
Allow 10% contingency	$248
Total per metre	$2728

18" Lines

Provision and installation of 48" carrier pipe including costs of shafts and conversion to chambers Price per metre	$1200
Provision of concrete bed, rollers and spacers Price per metre	$140
Cost of provision of branch pipes	
18" non-insulated per metre	$120
18" insulated pipe per metre	$200
Cost of installation etc	
18" non-insulated per metre	$135
18" insulated per metre	$200
Sub-total	$1995
Allow 10% contingency	$200
Total per metre	$2195

12" Lines

Provision and installation of 42" carrier pipe including costs of shafts and conversion to chambers Price per metre	£1050
Provision of concrete bed, rollers and spacers Price per metre	£130
Cost of provision of branch pipes	
12" non-insulated per metre	$90
12" insulated per metre	$150
Cost of installation etc	
12" non-insulated per metre	$90
12" insulated per metre	$150
Sub-total	$1660
Allow 10% contingency	$166
Total per metre	$1826

We have omitted the use of a carrier pipe on the 36" lines and assumed they would be direct installed in two separate lines. We would propose the use of a microtunnelling/ pipejacking solution which would probably be a two phase operation with the first phase being the installation of a temporary steel casing which at the second phase is pushed out be the permanent branch line pipes. A double drive and reception shaft arrangement would be designed to allow the two 36" pipes to be installed side by side.

An estimated total cost of installing each line including provision of steel pipe (temporary and permanent),shafts, etc would be $1500 per metre

The two lines would cost in total $3000 per metre

Alternative B

In this case for the 12", 18" and 24" lines we have assumed an outer carrier pipe of sufficient diameter to allow the insulated flow line to be located internally and the annular space to provide the return line. The outer pipe could be steel and installed as desribed for the 36" line. See sketch 3.

This will reduce the overall size of the carrier and eliminate the return pipe.

We estimate that the saving on the 24" lines will be $600 per metre, on the 18" lines $450 and on the 12" lines $350

This will give the following per metre rates

24" lines	$2128
18" lines	$1745
12" lines	$1476

Alternative C

We have adopted a different trenchless approach in this case and used guided boring technology adapted to suit the particular needs of this work.

In this case it is proposed to directly install into the ground separately the flow and return pipes. These pipes being suitably protected externally and internally for corrosion. The proposed method has been used for the installation of district heating lines.

We propose to install a monitored and guided pilot bore of about 2 to 3" diameter along each of the proposed centre lines followed by a reaming operation to enlarge the bore to the required size. The branch pipe itself would be installed by pulling in the sections behind the reamer. Bentonite drilling mud would be used to keep the bore open and lubricate/protect the pipe as it is drawn in.

We are proposing to use purpose built two part rigs which would use proven technology but be modified to work from pits rather than from the surface. There would be an advance rig for pilot boring and a heavier rig for the reaming and pull back operation. This is essentially a question of efficient working.

We would propose bore lengths of around 150 metres although 200 metres and longer are quite possible. Pit sizes would be say 6 metres long by 3 to 4 metres wide to allow for placing and jointing the steel pipes side by side. We have allowed a cost of $9000 per shaft including provision of a permanent access shaft. This equates for two bores to $30 per metre and is included in the boring cost. In practice it could be that every other shaft only would be a larger drive pit with intermediate reception pits being smaller.

Cost Estimate- Alternative C

24" Line

Cost of boring 24" diameter per metre $230	
Two bores @ $230	$460
Allow for supply and installation of pipe into bores as for alternative A costs	
non-insulated pipe metre $160 + $170	$310
insulated pipe per metre $300 + $300	$600
Sub-total	$1370
Allow 10% contingency	$137
Total per metre	$1507

18" Lines

Cost of boring 18" diameter per metre $190	
Two bores @ $190	$380
Allow for supply and installation of pipe into bores as for alternative A costs	
non-insulated pipe metre $120 + $135	$275
insulated pipe per metre $200 + $200	$400
Sub-total	$1035
Allow 10% contingency	$105
Total per metre	$1140

12" Lines

Cost of boring 12" diameter pipe per metre $160	
Two bores @ $160	$320
Allow for supply and installation of pipe into bores as for alternative A cost	
non-insulated pipe metre $90 + $90	$180
insulated pipe per metre $150 + $150	$300
Sub-total	$800
Allow 10% contingency	$80
Total per metre	$880

The cost of installing the 36" would be as in Alternative A.

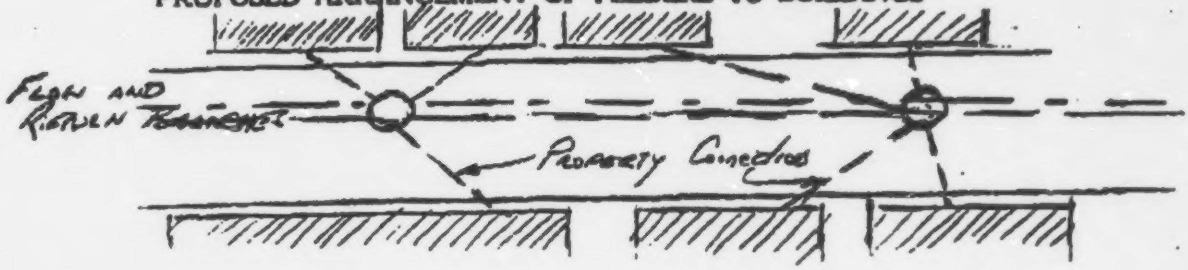
James Thomson C.Eng.
Jason Consultants SA

Geneva 24th April 1991
Amended 25th April 1991

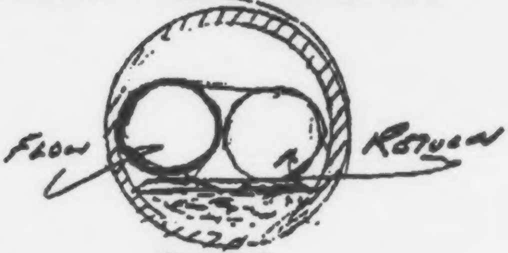
TABLE 1
FREECOOL PROJECT
COST OF STEEL PIPE FOR FEEDER LINES

Diameter	Supply$		Lay and joint $	
	Standard	Insulated	Standard	Insulated
12"	90	150	90	150
18"	120	200	135	200
24"	160	300	170	300
36"	230	450	200	450

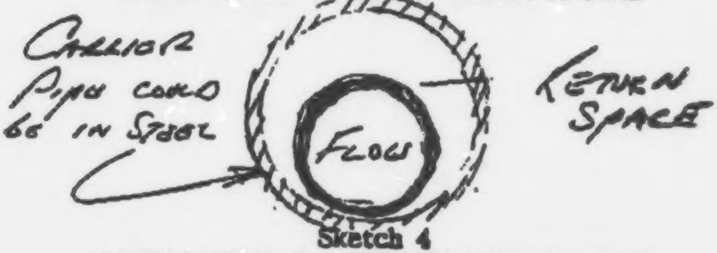
Sketch 1
PROPOSED ARRANGEMENT OF FEEDERS TO BUILDINGS


FLOW AND
RETURN BRANCHES
PROPERTY CONNECTIONS

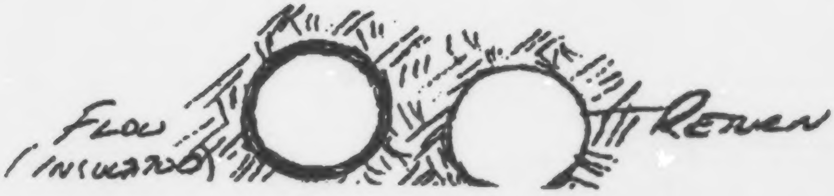
Sketch 2
ALTERNATIVE A - CARRIER PIPE


FLOW
RETURN

Sketch 3
ALTERNATIVE B - PIPE WITHIN A PIPE


CARRIER
PIPE COULD
BE IN STEEL
FLOW
RETURN
SPACE

Sketch 4
ALTERNATIVE C - DIRECT INSTALLATION


FLOW
(INSULATED)
RETURN

FREECOOL PROJECT - TORONTO
SUPPLEMENTARY REPORT ON CONNECTIONS OF BRANCHES TO MAIN FEEDERS

We omitted in our first review to comment on the way that we foresee the arrangement of connection between the large feeders and the cross street branch lines.

It is assumed that the main feeders along University and Yonge Streets will be located in the bedrock probably in the order of 15 to 20 metres to invert below the surface.

At each cross street intersection with University and Yonge a vertical shaft will be required to intersect on to the main feeders. Riser flow and return lines can be installed in the shaft and brought up to the branch working depth. Branch lines can be then fed out east and west along the cross streets.

These intersection shafts will be used as recepetion pits in the driving program.

The riser and branch pipework will all be standard welded steel construction with valves, bends and suchlike all designed in the normal way to the head requirements.

At this time we do not have Proctor and Redfern's scheme for the main feeder construction. With the heads envisaged we assume that the feeder line will have to be fabricated in steel. The provision of riser junctions on the feeder line could then be undertaken using standard practice.

APPENDIX C

Letter from Koch Engineering Company

KOCH

KOCH ENGINEERING COMPANY LTD

RECEIVED
APR 26 1991

23 April 1991

Engineering Interface Ltd.
2 Sheppard Avenue East, Suite 200
North York, Ontario
M2N 5Y7

Attention: Mr. R. Tamblyn

Re: T-D Centre

Dear Sir:

This will confirm our recent telephone discussion re high pressure water-water plate exchangers for the above complex (and possibly others).

For 12,000 USGPM being cooled 54 to 42°F by an equal flow heating from 40 to 52°F with 25 feet of pressure drop each side and considering a maximum cooler height of eight feet, we would require a total of eight of our frame size 145 connected two in series by four in parallel. See attached dimension sheet for dimensions of frame 145.

In this frame size we can offer a maximum of 350 PSI operating pressure each side independently. Our normal maximum operating pressure is 250 PSI for the standard 0.5 mm thick plate. At 300 PSI we use 0.6 mm plates and at 350 PSI we use 0.7 mm.

For a design pressure of 300 PSI the cost of eight of these exchangers would be about $500,000 based on 304 SS plates and nitrile (S) gaskets. The height limitation of eight feet has a significant effect on this price, for example at a height of twelve foot six inches we require four frame size 265 at a price of about $400,000.

Our present plate design is the UFX and we attach herewith a detailed description of the advantages of this plate together with our brochure (currently being revised to reflect the UFX design and additional frame sizes now available).

Yours very truly,

KOCH ENGINEERING COMPANY LIMITED

W. Peter Barker
Executive Vice-President
Marketing & Sales

WPB:ec

APPENDIX C

4750 Sheppard Avenue East • Agincourt, Ontario, Canada M1S 3V7
416/293-3666 • TLX 06525275 • Telecopier 416/293-6409

APPENDIX D

Questionnaire for Building Owners

3.0 QUESTIONNAIRE FOR BUILDING OWNERS

1. BUILDING PARTICULARS

Name of Building ____________

Address ____________

Owner ____________

Chief Operator ____________

Size of Building ______ft^2 gross

2. CHILLER DESCRIPTION

Tons Capacity

Unit #1

Unit #2

Unit #3

Unit #4 ______

Total

Manufacture: ____________

____

Model Numbers ____________

____

____

Location: Draw Sketch

Duty: Cool ______ gpm from ____°F to ____°F

Age of Chillers: ______ years

______ years

______ years

Kilowatt Input from Motor Nameplates:

#1

#2

#3

#4 ______

Total

Type Refrigerant: ____________

Area Required for Chillers ____________ft^2

3. CONDENSING WATER PUMPS

Number ________

Capacity ________ gpm

Kilowatt Input ________ kW

Location ________ Show on Sketch

Area Required ________ft^2

4. WATER TOWERS

Location ________

Number of Fans ________

Kilowatt Input ________ kW

Area to be Salvaged ________ ft^2

Winter Precooling Potential ☐ Yes ☐ No

5. SERVICE CONTRACTS

Chillers $______/yr.

Towers $______/yr.

Water Treatment & Chemicals $______/yr.

6. REPAIRS IN PAST 5 YEARS

$________ /yr.

7. MANPOWER ALLOCATED TO LOG SHEETS, REPAIRS, WATER TREATMENT, ETC.

$________ /yr.

8. ACTUAL TONS REQUIRED

Maximum Summer ______

Maximum Winter ______

9. CHILLER OPERATING REGIMEN

Hrs/day ______

Months/yr. ______

10. LAYOUT OF BASEMENT

Sketch to show best location of new piping and heat exchanger.

11. ATTITUDE OF OWNER

Objection, if any, to running lines through basement.

Prepared to pay up to ______¢/ton hour for 5.5°C, or less, lake water delivered to a new heat exchanger in my building, if the system is proven reliable.

12. OTHER REMARKS BY OWNER

APPENDIX E

Freecool Scenario - Support of Building Owner

FREECOOL SCENARIO - SUPPORT OF BUILDING OWNER

Given the Freecool scenario, as outlined in the attached brief, that is:

1. To supply lower cost year-round cooling to downtown buildings.
2. To reduce Hydro's carbon dioxide emissions.
3. To reduce CFC usage by removing reliance on chiller cooling.

Would you support this system by allowing two cool water pipes to run through the basement of your building?

YES ____ NO ____

If no, what objections do you have, and how could we work towards removing them:

____

____

Do you have any other remarks:

____

____

____

____

Signature:

____

Date: ____________

Name: ____________________

Position: __________________

Company: _________________

Building Referred to:

____

APPENDIX E

APPENDIX F

Letter from Dr. G. Mackie re Zebra Mussel Problem

RECEIVED
FEB 6 1991

February 3, 1991

Mr. R. T. Tamblyn
Engineering Interface Limited
Suite 200, 2 Sheppard Avenue E.
North York, Ontario
M2N 5Y7

Dear Bob:

Thank you for your letter of January 30, 1991, concerning the use of Freecool for eliminating zebra mussel infestations.

There is no question, in my opinion, that intakes at 80 m, permanently in 4 °C water, will NOT develop zebra mussel infestations, even if the intake velocity is less than 75 mm sec^{-1}. I have several reasons for this answer: First, at 4 °C adults will not grow because the threshold temperature for growth is 8 to 12 °C (the literature reports 10 - 12 °C but we have evidence to indicate that growth begins around 8 °C). Secondly, the temperature threshold for reproduction is even higher, i.e. 15 to 17 °C, and, therefore, the adults will not be able to reproduce at 4 °C. This is significant because it is the reproductive process that is responsible for massive infestations. Thirdly, the maximum depth in which adult and larval zebra mussels have EVER been reported is 50 m.

I have two concerns that need to be addressed. First, because 4 °C water will not kill adults, or even settling stages of larvae, I am concerned that some mussels, especially young adults, may survive passage in the hypolimnetic intake water into the industries and utilities and settle in pipes where water temperatures may be appropriate for growth and reproduction. In order to address this concern I would need more details. For example, I would need to know the range of temperatures, range of water velocities and retention time in the distribution system. Also, Lake Ontario is subject to severe internal seiches (rocking of the thermocline) which may periodically introduce warmer, epilimnetic water into the intake structure. Of course, the deeper the intake structure, the less likely that this will occur. I am also somewhat concerned about the environmental impacts of large numbers of industries and utilities using this approach, especially if the water demands exceed the total volume of the hypolimnion. Some utilities require 500,000 or even 1,000,000 gal min^{-1} as coolant; what is the maximum total demand if every industry and utility used hypolimnetic water? Will the demands lower the volume of the hypolimnion to the point that the cold water fisheries (e.g. trout, salmon, whitefish) will be affected? If there is a potential effect, it may be possible to mix hypolimnetic water with epilimnetic water to produce temperatures that are less than 10 °C (to prevent growth), or even less than 15 °C (to prevent reproduction). I suspect Freecool is more effective at cooler temperatures, so 10 °C will be preferred over 15 °C. However, even at 10 °C you can significantly reduce the demand of hypolimnetic water, perhaps by as much as 50%, according to my "back-of-the-envelope" calculation.

As far as outfalls are concerned, neither adults nor larvae can crawl or swim against water velocities varying up to 1 m sec^{-1}. If adults were found on the outfall pipe, they would have to originate in the influent water and survive passage through the plant to the outfall. Even if a few survived passage, the 12.5 °C temperature is insufficient for reproduction to occur. By outfall, I assume you mean a place where water is returned to the lake; if so, I would increase the water velocity, not decrease it. Mussels will not settle at velocities exceeding 1.5 m sec^{-1}.

I hope I have provided enough information for you to enter as a position statement for using Freecool.

Sincerely yours,

Gerry

Gerry Mackie
President

Mackie and Associates Water Systems Analysts
23 Avra Court. GUELPH. Ontario N1H 7B2 PH: (519) ~~823-2755~~ 837-3613

Mackie and Associates Water Systems Analysts Inc.
23 Avra Court. GUELPH, Ontario
Canada. N1H 7B2
FAX & Phone: (519) 837-3813

PROPOSAL FOR MONITORING ZEBRA MUSSELS IN FREECOOL SYSTEMS

Introduction:

The zebra mussel is a bivalve mollusc that was introduced into the Great Lakes in the ballast of an ocean-going vessel in 1985 or earlier. It is rapidly becoming the most serious and devastating pest of any exotic species that has ever been introduced to North America surface waters. For more than 100 years, Europeans have documented its ability to: (i) clog intakes, service water systems and fire protection systems in industrial and domestic facilities; (ii) corrode steel and cast iron pipes; (iii) taint and contaminate potable water supplies; and (iv) encrust hulls of boats and ships. In the past 3 years, utilities, industries, water treatment plants, fishermen and boaters in the Great Lakes, especially Lake Erie, have already seen these effects and in addition have documented: (v) fouling and rendering useless fishing gear and navigational aids (e.g. buoys); (vi) reduction, or possibly elimination, of the recreational and aesthetic value of beaches and shorelines; (vii) displacement of native species of bivalves; and (viii) alteration or even destruction of fish habitats.

The epicentre of zebra mussel invasion for the Great Lakes, and ultimately for all North American surface waters is Lake St. Clair where mussels have been present since at least 1985. Younger populations are present in the western basin of Lake Erie and new populations are appearing in an easterly direction (i.e. downstream with currents) at a rate of approximately 250 km/yr. The most easterly occurrence of the mussel is now (February, 1991) at Prescott in the St. Lawrence River. In 1991 veliger larvae were found in at least in 75% of Lake Ontario, although adults were found in only the west end of Lake Ontario, with local populations as far as Kingston on the Ontario side and Rochester on the U.S. side of Lake Ontario. Adults have also been found in all the other Great Lakes, although in localized populations and often on "mpving substrates" (e.g. hulls of boats and ships). The zebra mussel is also beginning to find its way inland, with confirmed reports in the Ottawa River and Rideau Rivers in Ontario, Genesee River in New York, and the Mississippi River in Illinois. Since downstream dispersal is effected mainly by the planktonic veliger larvae stage, which is most common in the summer months, the most rapid dispersal occurs during the summer and fall. Adults readily attach to the hulls of boats and ships which will carry and spread the mussel into all the Great Lakes in both upstream and downstream directions.

Reproduction begins in the winter, veligers appear in June and are present throughout the summer until late November or even December. There may be one or two periods of peak abundances of veliger larvae; if there are two periods, the peaks usually occur in July and August or September; if one period, the peak usually occurs in August. Settlement usually occurs 4 to 5 weeks after the peaks in veliger abundance is observed. Over 90% of postveliger settlement usually occurs within a 2 week period, and there may be one or two of these settlement events each year. Variations in the timing of these events occur within even a few kilometers on the same lake or canal (e.g. Welland Canal). The growth rate of adults is phenomenal, as much as 2 cm yr^{-1}. The young mussels attach themselves immediately to any solid substrate (although there are materials that they avoid, e.g. copper) but detach and move about quite readily, especially in their first year of life. The frequency of detachment decreases with increasing age. Industries and utilities can expect adult infestations to occur one year after massive numbers (e.g. > 10,000 m^{-3}) of veliger larvae are first discovered in the intake water.

"The older they get, the tougher they get", is a general rule that will dictate the type of control program to be used to eliminate zebra mussels from a facility. There are physical, chemical and mechanical methods available to control the spread and growth of zebra mussels within a facility, but generally the older they get the more difficult it is to remove them, and the more expensive the control program. Mussel monitors must be used to detect larvae entering intakes, forebays, wet wells or other intake areas before they settle and grow in the service water and fire protection systems. Mussel monitors are also needed to detect settlement within the distribution system and to evaluate the effectiveness of a control program.

No industry, utility, water treatment plant or commercial user/consumer of water from the Great Lakes is immune to biofouling by the zebra mussel, except perhaps those whose intakes are in water permanently at 4 °C (e.g. 75 m depth of Lake Ontario). The zebra mussel is here to stay and cannot be eliminated from the Great Lakes. Control programs must be applied at or within the facilities affected as early as possible. The types of control programs vary from one facility to the next, and even within a facility. The timing and duration of the control programs will also vary from one facility to the next.

Infestation Potential of Intakes at 80 m Depth and Outfalls at 6 m Depth:

It is highly inlikely that intakes at 80 m depths, permanently in 4 °C water, will develop zebra mussel infestations, even if intake velocities are less than 75 mm sec^{-1} (zebra mussels will not settle at water velocities exceeding 1.5 m sec^{-1}). There are several reasons for this answer: First, at 4 °C adults will not grow because the threshold temperature for growth is 8 to 12 °C (the literature reports 10 - 12 °C but MAWSA has evidence to indicate that growth begins around 8 °C). Secondly, the temperature threshold for reproduction is even higher, i.e. 15 to 17 °C, and, therefore, the adults will not be able to reproduce at 4 °C. This is significant because it is the reproductive process that is responsible for massive infestations. Thirdly, the maximum depth in which adult and larval zebra mussels have EVER been reported is 50 m. Typically, zebra mussel populations are significantly reduced or even absent below 20 m.

However, there are two concerns that need to be addressed. First, because 4 °C water will not kill adults, or even settling stages of larvae, that some mussels, especially young adults, may survive passage in the hypolimnetic intake water into the industries and utilities and settle in pipes where water temperatures may be appropriate for growth and reproduction. In order to address this concern more details are required. For example, it is necessary to know the range of temperatures, range of water velocities and retention time of water in the distribution system. Also, Lake Ontario is subject to severe internal seiches (rocking of the thermocline) which may periodically introduce warmer, epilimnetic water into the intake structure. Of course, the deeper the intake structure, the less likely that this will occur. It is also important to know the environmental impacts of large numbers of industries and utilities using this approach, especially if the water demands exceed the total volume of the hypolimnion. Some utilities require 500,000 or even 1,000,000 gal min^{-1} as coolant; what is the maximum total demand if every industry and utility used hypolimnetic water? Will the demands lower the volume of the hypolimnion to the point that the cold water fisheries (e.g. trout, salmon, whitefish) will be affected? If there is a potential effect, it may be possible to mix hypolimnetic water with epilimnetic water to produce temperatures that are less than 10 °C (to prevent growth), or even less than 15 °C (to prevent reproduction).

With respect to the outfalls, neither adults nor larvae can crawl or swim against water velocities varying up to 1 m sec^{-1}. If adults are found on the outfall pipe, they would have to originate in the influent water and survive passage through the plant to the outfall. Even if a few survived passage, temperatures less than 13 °C are insufficient for reproduction to occur.

Proposal:

Although the literature supports the contentions described above, there are no data from North America, especially Lake Ontario, to confirm them. It will be necessary in the first year at least to collect data to show definitively that intakes at 80 m depths are not susceptible to zebra mussel infestations. The data required are weekly estimates of: (1) veliger larvae abundance, if any; (2) survival of veliger larvae found; (3) veliger larval growth rate, if any; and (4) postveliger settling rates, if any. These data will be compared to data collected from a "control" site (i.e. a site in the area, but in the epilimnion, that will permit estimates of abundance and of rates of growth, survival and settling of veliger larvae). The control site will allow us to state definitively that the absence of zebra mussels is due to the position of the intake structure and not to the absence of viable veliger larvae in the area. MAWSA already has over 12 other sites, 5 of which are in Lake Ontario and 7 in Lake Erie to show variations in the same demographic features of zebra mussels.

A MAWSA mussel monitor will be set up on the intake supply line. Samples of water will be taken from the monitor at least weekly to determine abundance of veliger larvae and biweekly (if necessary) to determine growth, survival and settling rates of veligers. Settling rates will be determined from the numbers of postveligers settling on settling plates in the mussel monitor. Ideally, the control monitor should sample water directly above the intake structure, but from the 3 to 7 m depth where veliger abundance is usually maximum. However, since the depth of peak abundance of veligers tends to be more or less uniform throughout the lake, the numbers of veligers in samples taken from several locations (e.g. Niagara-on-the-Lake, Grimsby, Oakville, Picton, Rochester) probably reflect those taken 3.7 km off shore where the intake structure is located.

At least two site visits will be required. The first site visit will be useful for preparing design briefs with respect to monitoring zebra mussels when recommending Freecool for the project. During the site visit I would especially like to look at: (1) historical data on daily and seasonal variations in temperature and pH of the water throughout the distribution system; (2) potential mussel monitoring location with respect to exact locations and sizes of valves, drains and electrical supplies; and (3) other factors that might play a role in the final design and preparation of specifications for monitoring (and controlling, if necessary) zebra mussels. I suspect that 4 hours will be sufficient for the first site visit. The second site visit will be required to deliver and install the mussel monitor and will require 2 hours.

The mussel monitoring program I would recommend is the "Mail-In" Program. The program is useful only in detection programs where water samples are examined only to determine the first occurrence, numbers and sizes of veliger larvae. Employees at the pumping station are taught how to take water samples from the mussel monitor, preserve them and send them by express mail to MAWSA in Guelph. The program is at about one-half the cost if MAWSA took the samples. For example, MAWSA supplies the pre-addressed mailing tubes and vials but the client pays for costs of express mailing the samples at weekly to biweekly intervals. MAWSA will supply a schedule for sampling. The cost for each analysis is $165 (x 20 analyses = $3300). Express mail costs are approximately $15/mailing (x 20 = $300). The total costs of analyses to the client is $3300 + $300 = $3600. If MAWSA took the samples, the client must pay for labour involved (about $120/sample x 20 = $2400), mileage (about $0.30/mi or $40/trip x 20 trips = $800) and analyses ($165 x 20 = $3300), for a total cost of $6500.

The cost of the mussel monitoring program is as follows:

Delivery and installation	$300.00
Rental of MAWSA mussel monitor and sampling gear (May to December)	900.00
20 analyses of express-mailed veliger larvae samples	3300.00
Data interpretation and report (December, 1991)	500.00
TOTAL COST OF MONITORING	$5,000.00

I charge $100/hr or $800/day for my services, plus expenses. The above costs for delivery and installation ($300) include costs of one person to help me install the monitor, but it does not include the costs for my services or expenses. The above scenario requires 6 hours for my services (4 hours for first site visit, 2 hours for second), or a total of $600 plus expenses. According to your letter of January 30, 1991, Engineering Interface Limited may also wish to employ my services for other aspects of this proposal (e.g. charrette in mid-June).

Sincerely yours,

Gerry

Gerry Mackie
President

APPENDIX F-4

APPENDIX G

Computer Based Spreadsheets

- Base Case
- Slow Track
- Fast Track
- Customer Shortfall (Slow Connect)
- Customer Shortfall (Low Usage)
- Cost Overruns

FIGURE 23
OPERATING COST OF CUSTOMERS' ORIGINAL ON-SITE COOLING PLANT

ALL AMOUNTS IN $000

COL.1	COL.2	COL.3	COL.4	COL.5	COL.6	COL.7	COL.8	COL.9	COL.10	COL.11	COL.12	COL.13	COL.14	COL.15
	ELECTRICITY COSTS			SERVICING COSTS					ADDED CHILLER CAPACITY COSTS $000				PRESENT WORTH FOR YEAR	
YEAR	CENTRAL (160,000 TONS)	COMP'T (40,000 TONS)	80/20 BLEND TOTAL	CENTRAL	COMP'T	80/20 BLEND TOTAL	AMORTIZED ORIGINAL 200 KTONS @ 10.6%	INITIAL SYSTEM COST	AMORTIZED CAPACITY	OPERATING COSTS	NET COST SUM OF COLS. 9 TO 11	CENTS PER TON-HR	10% FACTOR	PW ($000)
1991	27349	9603	36952	3840	1120	4960	16973	58885	288	713	59887	22.98		
1992	28716	10083	38800	4032	1176	5208	16973	60981	596	1510	63087	23.80		
1993	30152	10587	40740	4234	1235	5468	16973	63181	925	2399	66505	24.67		
1994	31660	11117	42777	4445	1297	5742	16973	65491	1276	3388	70155	25.59		
1995	33243	11673	44915	4668	1361	6029	16973	67917	1651	4484	74053	26.56		
1996	34905	12256	47161	4901	1429	6330	16973	70465	2051	5699	78215	27.59		
1997	36650	12869	49519	5146	1501	6647	16973	73139	2479	7041	82659	28.67		
1998	38483	13512	51995	5403	1576	6979	16973	75947	2935	8522	87405	29.81		
1999	40407	14188	54595	5673	1655	7328	16973	78896	3423	10154	92473	31.01	1.00	92473
2000	42427	14897	57325	5957	1737	7695	16973	81992	3943	11950	97885	32.27	0.90	88097
2001	44549	15642	60191	6255	1824	8079	16973	85243	4499	13922	103665	33.61	0.81	83968
2002	46776	16424	63200	6568	1916	8483	16973	88657	5093	16087	109836	35.01	0.73	80071
2003	49115	17246	66360	6896	2011	8907	16973	92241	5727	18459	116426	36.49	0.66	76387
2004	51571	18108	69679	7241	2112	9353	16973	96004	6404	21056	123464	38.05	0.59	72904
2005	54149	19013	73162	7603	2218	9820	16973	99956	7126	23897	130979	39.69	0.53	69608
2006	56857	19964	76821	7983	2328	10311	16973	104105	7898	27001	139004	41.42	0.48	66485
2007	59699	20962	80662	8382	2445	10827	16973	108462	8722	30390	147574	43.24	0.43	63526
2008	62684	22010	84695	8801	2567	11368	16973	113036	9603	34086	156725	45.16	0.39	60718
2009	65819	23111	88929	9241	2695	11937	16973	117839	10542	38115	166497	47.17	0.35	58054
2010	69110	24266	93376	9703	2830	12534	16973	122883	11546	42504	176932	49.29	0.31	55523
2011	72565	25480	98045	10189	2972	13160	16973	128178	12618	47280	188076	51.52	0.28	53118
2012	76193	26754	102947	10698	3120	13818	16973	133738	13762	52475	199975	53.86	0.25	50831
2013	80003	28091	108094	11233	3276	14509	16973	139577	14984	58121	212682	56.32	0.23	48655
2014	84003	29496	113499	11795	3440	15235	16973	145707	16289	64256	226251	58.92	0.21	46583
2015	88203	30971	119174	12384	3612	15996	16973	152143	16363	67650	236155	60.47	0.19	43760
2016	92613	32519	125133	13004	3793	16796	16973	158902	16363	71032	246297	63.01	0.17	41075
2017	97244	34145	131389	13654	3982	17636	16973	165998	16363	74584	256945	65.73	0.15	38566
2018	102106	35852	137959	14336	4181	18518	16973	173450	16363	78313	268125	68.59	0.14	36220
2019	107212	37645	144857	15053	4391	19444	16973	181273	16363	82229	279865	71.59	0.12	34025
2020	112572	39527	152099	15806	4610	20416	16973	189488	16363	86340	292191	74.75	0.11	31971
2021	118201	41504	159704	16596	4841	21437	69862	251003	16363	90657	358023	91.59	0.10	35257
2022	124111	43579	167690	17426	5083	22509	69862	260060	16363	95190	371613	95.07	0.09	32936
2023	130316	45758	176074	18297	5337	23634	69862	269570	16363	99949	385882	98.72	0.08	30780
2024	136832	48046	184878	19212	5604	24816	69862	279556	16363	104947	400865	102.55	0.07	28778
2025	143674	50448	194122	20173	5884	26057	69862	290040	16363	110194	416597	106.57	0.06	26917
2026	150858	52970	203828	21181	6178	27359	69862	301049	16363	115704	433116	110.80	0.06	25186
2027	158400	55619	214019	22241	6487	28727	69862	312609	16363	121489	450460	115.24	0.05	23575
2028	166320	58400	224720	23353	6811	30164	69862	324746	16363	127564	468672	119.90	0.05	22075
2029	174636	61320	235956	24520	7152	31672	69862	337490	16363	133942	487794	124.79	0.04	20678
2030	183368	64386	247754	25746	7509	33256	69862	350872	16363	140639	507873	129.92	0.04	19376
2031	192537	67605	260142	27034	7885	34918	69862	364922	16363	147671	528955	135.32	0.03	18163
2032	202163	70985	273149	28385	8279	36664	69862	379675	16363	155054	551092	140.98	0.03	17030
2033	212272	74535	286806	29804	8693	38497	69862	395166	16363	162807	574335	146.93	0.03	15974
2034	222885	78261	301146	31295	9128	40422	69862	411431	16363	170947	598741	153.17	0.03	14987
2035	234030	82174	316204	32859	9584	42443	69862	428509	16363	179495	624367	159.73	0.02	14066
2036	245731	86283	332014	34502	10063	44566	69862	446442	16363	188470	651274	166.61	0.02	13205
2037	258018	90597	348615	36228	10566	46794	69862	465271	16363	197893	679526	173.84	0.02	12400
2038	270918	95127	366045	38039	11095	49134	69862	485041	16363	207788	709191	181.43	0.02	11647
2039	284464	99883	384348	39941	11649	51590	69862	505800	16363	218177	740340	189.39	0.01	10943
2040	298688	104878	403565	41938	12232	54170	69862	527597	16363	229086	773045	197.76	0.01	10284
TOTAL	5725458	2010369	7735827	803896	234470	1038366	1906430	10680623	579807	4001319	15261749			1696876

[redacted]ES: [redacted]NG [redacted] END[redacted]TER [redacted]TH Y[redacted] [redacted]
AMORTIZATION OF [redacted] CHILL[redacted] BEGINS BEF[redacted]ELEV[redacted] YE[redacted] [redacted] [redacted] [redacted] [redacted] [redacted] [redacted] [redacted] [redacted] [redacted] [redacted]
BASED ON $1707/TON FOR CHILLERS AFTER TENTH YEAR

FIGURE 25

CALCULATION OF INITIAL COST ($ 000) BASE CASE

COL.1	COL.2	COL.3	COL.4	COL.5	COL.6	COL.7	COL.8	COL.9	COL.10	COL.11	COL.12	COL.13
	ENGINEERING COSTS											
YEAR	MECH. & ELECTRIC	ENV. STUDIES	LEGAL	CONTRACT	CONTINGENCY	HEAT EX.	CUSTOMER CONN'S	CUSTOMER ENG.	15% TAXES	TOTAL	INTEREST MULTIPLIER	TOTAL
1992	5000	1000	100	0	0	0	0	0	915	7015	1.95	13670.3
1993	1000	1000	100	0	0	0	0	0	315	2415	1.77	4278.3
1994	1000	1000	100	0	0	0	0	0	315	2415	1.61	3889.4
1995	7000	0	100	0	0	0	0	0	1065	8165	1.46	11954.4
1996	7000	0	100	77000	7500	0	0	0	13740	105340	1.33	140207.5
1997	1500	0	100	81000	8000	0	0	0	13590	104190	1.21	126069.9
1998	1500	0	100	85000	8500	33500	107200	10000	36870	282670	1.10	310937.0
TOTAL	24000	3000	700	243000	24000	33500	107200	10000	66810	512210		611006.8

ONTARIO HYDRO INCENTIVE FOR YEAR 1999 ($591/TON, 228875 TONS)		135265.0
NET INITIAL COST:		475741.8
COST OF INTERIM FINANCE:	(611007-512210)	98796.8

FIGURE 27
COST OF LAKEWATER COOLING BASE CASE

							HEAT EXCHANGERS		HEAT EX. AMORTIZED		ADMIN. COSTS $000		HYDRO INCENTIVES		NET COSTS			
COL.2 SYSTEM TONS	COL.3 MILLION TON-HOURS	COL.4 300 K-TON ENERGY ($ 000)	COL.5 PUMP WORK FACTOR	COL.6 ACTUAL ENERGY ($ 000)	COL.7 PLANT COST AMORTIZED ($ 000)	COL.8 TONS	COL.9 TOTAL NEW TONS	COL.10 COST/ NEW TON ($)	COL.11 ANNUAL COST $000	COL.12 TOTAL COST $000	COL.13 SALARIES	COL.14 REPAIRS, ETC.	COL.15 INCENTIVE $ PER TON	COL.16 TOTAL ($000)	COL.17 COL.6+7+ 12TO14-16 ($000)	COL.18 TOTAL CENTS/ TON-HR	COL.19 COST 10% INT FACTOR	COL.2 PRESE WORT ($000
228875	298.22	3971	0.509	2021	48526	3825	3825	176	71	71	369	295	591	2261	49022	16.44	1.00	490
232765	303.29	4170	0.518	2160	48526	3890	7716	185	76	147	388	310	621	2414	49117	16.19	0.90	442
236722	308.45	4379	0.530	2321	48526	3957	11673	194	81	229	407	326	652	2578	49230	15.96	0.81	398
240747	313.69	4597	0.545	2506	48526	4024	15697	204	87	316	428	342	684	2753	49363	15.74	0.73	359
244839	319.03	4827	0.567	2737	48526	4093	19790	214	93	408	449	359	718	2940	49539	15.53	0.66	325
249002	324.45	5069	0.591	2996	48526	4162	23952	224	99	507	471	377	754	3139	49738	15.33	0.59	293
253235	329.96	5322	0.613	3262	48526	4233	28185	236	106	613	495	396	792	3352	49940	15.13	0.53	265
257540	335.57	5588	0.642	3588	48526	4305	32490	247	113	726	520	416	832	3580	50195	14.96	0.48	240
261918	341.28	5868	0.670	3931	48526	4378	36868	260	121	847	546	437	873	3823	50463	14.79	0.43	217.
266371	347.08	6161	0.699	4307	48526	4453	41321	273	129	976	573	458	917	4082	50757	14.62	0.39	196
270899	352.98	6469	0.729	4716	48526	4528	45849	287	138	1113	602	481	963	4359	51078	14.47	0.35	178
275504	358.98	6792	0.761	5169	48526	4605	50455	301	147	1260	632	505	1011	4655	51437	14.33	0.31	161
280188	365.08	7132	0.802	5720	48526	4684	55138	316	157	1417	663	531	1061	4971	51886	14.21	0.28	146
284951	371.29	7489	0.851	6373	48526	4763	59901	332	167	1584	696	557	1114	5308	52428	14.12	0.25	133
289795	377.60	7863	0.900	7077	48526	4844	64745	348	179	1763	731	585	1170	5668	53014	14.04	0.23	121
294722	384.02	8256	0.949	7835	48526	4927	69672	366	191	1954	768	614	1229	6053	53644	13.97	0.21	110
299732	390.55	8669	0.999	8660	48526	5010	74682	384	204	2158	806	645	1290	6463	54332	13.91	0.19	100
300000	390.90	9103	1.000	9103	48526	268	74950	403	11	2169	847	677	1355	363	60958	15.59	0.17	101
300000	390.90	9558	1.000	9558	48526	0	74950	423	0	2169	889	711	1422	0	61853	15.82	0.15	92
300000	390.90	10036	1.000	10036	48526	0	74950	444	0	2169	933	747	1493	0	62411	15.97	0.14	84
300000	390.90	10537	1.000	10537	48526	0	74950	467	0	2169	980	784	1568	0	62996	16.12	0.12	76
300000	390.90	11064	1.000	11064	48526	0	74950	490	0	2169	1029	823	1646	0	63611	16.27	0.11	69
300000	390.90	11617	1.000	11617	48526	0	74950	515	0	2169	1080	864	1729	0	64257	16.44	0.10	63.
300000	390.90	12198	1.000	12198	48526	0	74950	540	0	2169	1135	908	1815	0	64935	16.61	0.09	57
300000	390.90	12808	1.000	12808	48526	0	74950	567	0	2169	1191	953	1906	0	65647	16.79	0.08	52
300000	390.90	13449	1.000	13449	48526	0	74950	596	0	2169	1251	1001	2001	0	66395	16.99	0.07	47
300000	390.90	14121	1.000	14121	48526	0	74950	625	0	2169	1313	1051	2101	0	67180	17.19	0.06	43
300000	390.90	14827	1.000	14827	48526	0	74950	657	0	2169	1379	1103	2206	0	68004	17.40	0.06	39
300000	390.90	15569	1.000	15569	48526	0	74950	690	0	2169	1448	1158	2317	0	68870	17.62	0.05	36
300000	390.90	16347	1.000	16347	48526	0	74950	724	0	2098	1520	1216	2433	0	69707	17.83	0.05	32
300000	390.90	17164	1.000	17164	48526	0	74950	760	0	2022	1596	1277	2554	0	70585	18.06	0.04	29
300000	390.90	18022	1.000	18022	48526	0	74950	798	0	1941	1676	1341	2682	0	71506	18.29	0.04	27.
300000	390.90	18924	1.000	18924	48526	0	74950	838	0	1854	1760	1408	2816	0	72471	18.54	0.03	24
300000	390.90	19870	1.000	19870	48526	0	74950	880	0	1761	1848	1478	2957	0	73483	18.80	0.03	22
300000	390.90	20863	1.000	20863	48526	0	74950	924	0	1662	1940	1552	3105	0	74544	19.07	0.03	20.
300000	390.90	21906	1.000	21906	48526	0	74950	970	0	1556	2037	1630	3260	0	75656	19.35	0.03	18
300000	390.90	23002	1.000	23002	48526	0	74950	1019	0	1443	2139	1711	3423	0	76821	19.65	0.02	17.
300000	390.90	24152	1.000	24152	48526	0	74950	1070	0	1323	2246	1797	3594	0	78043	19.97	0.02	15
300000	390.90	25359	1.000	25359	48526	0	74950	1125	0	1194	2359	1887	3774	0	79324	20.29	0.02	14
300000	390.90	26627	1.000	26627	48526	0	74950	1179	0	1056	2476	1981	3962	0	80667	20.64	0.02	13.
300000	390.90	27959	1.000	27959	48526	0	74950	1238	0	909	2600	2080	4161	0	82074	21.00	0.01	12
300000	390.90	29357	1.000	29357	0	0	74950	1300	0	753	2730	2184	4369	0	35024	8.96	0.01	4
	15295.82			507797	1941026						49580	39664		66503	2533106			4710.

-- PUMP ENERGY IS NOT PROPORTIONAL TO SYSTEM TONS.
LARGER TONNAGES ARE PUMPED AT GREATER FRICTION FACTOR.
SEE FIGURE 18 FOR FRICTION CURVE.

— FRICTION CURVE BASED ON 300000 TON SIZING [illegible]IGURE 25

[illegible]ERATI[illegible]COST [illegible]CUST[illegible]S' [illegible]NAL [illegible]SIT[illegible] LIN[illegible]NT [illegible]V C[illegible]

ALL AMOUNTS IN $000

COL.1 YEAR	COL.2 ELECTRICITY COSTS CENTRAL (160,000 TONS)	COL.3 ELECTRICITY COSTS COMP'T (40,000 TONS)	COL.4 ELECTRICITY COSTS 80/20 BLEND TOTAL	COL.5 SERVICING COSTS CENTRAL	COL.6 SERVICING COSTS COMP'T	COL.7 80/20 BLEND TOTAL	COL.8 AMORTIZED ORIGINAL 200 KTONS @ 10.6%	COL.9 INITIAL SYSTEM COST	COL.10 ADDED CHILLER CAPACITY COSTS $000 AMORTIZED CAPACITY	COL.11 ADDED CHILLER CAPACITY COSTS $000 OPERATING COSTS	COL.12 NET COST SUM OF COLS. 9 TO 11	COL.13 CENTS PER TON-HR	COL.14 PRESENT WORTH FOR YEAR 10% FACTOR	COL.15 PRESENT WORTH PW ($000)
1991	27349	9603	36952	3840	1120	4960	16973	58885	288	713	59887	22.98		
1992	28716	10083	38800	4032	1176	5208	16973	60981	596	1510	63087	23.80		
1993	30152	10587	40740	4234	1235	5468	16973	63181	925	2399	66505	24.67		
1994	31660	11117	42777	4445	1297	5742	16973	65491	1276	3388	70155	25.59		
1995	33243	11673	44915	4668	1361	6029	16973	67917	1651	4484	74053	26.56		
1996	34905	12256	47161	4901	1429	6330	16973	70465	2051	5699	78215	27.59		
1997	36650	12869	49519	5146	1501	6647	16973	73139	2479	7041	82659	28.67		
1998	38483	13512	51995	5403	1576	6979	16973	75947	2935	8522	87405	29.81		0
1999	40407	14188	54595	5673	1655	7328	16973	78896	3423	10154	92473	31.01		0
2000	42427	14897	57325	5957	1737	7695	16973	81992	3943	11950	97885	32.27		0
2001	44549	15642	60191	6255	1824	8079	16973	85243	4499	13922	103665	33.61		
2002	46776	16424	63200	6568	1916	8483	16973	88657	5093	16087	109836	35.01	1.00	109836
2003	49115	17246	66360	6896	2011	8907	16973	92241	5727	18459	116426	36.49	0.90	104784
2004	51571	18108	69679	7241	2112	9353	16973	96004	6404	21056	123464	38.05	0.81	100006
2005	54149	19013	73162	7603	2218	9820	16973	99956	7126	23897	130979	39.69	0.73	95484
2006	56857	19964	76821	7983	2328	10311	16973	104105	7898	27001	139004	41.42	0.66	91201
2007	59699	20962	00662	8382	2445	10827	16973	108462	8722	30390	147574	43.24	0.59	87141
2008	62684	22010	84695	8801	2567	11368	16973	113036	9603	34086	156725	45.16	0.53	83290
2009	65819	23111	88929	9241	2695	11937	16973	117839	10542	38115	166497	47.17	0.48	79635
2010	69110	24266	93376	9703	2830	12534	16973	122883	11546	42504	176932	49.29	0.43	76164
2011	72565	25480	98045	10189	2972	13160	16973	128178	12618	47280	188076	51.52	0.39	72864
2012	76193	26754	102947	10698	3120	13818	16973	133738	13762	52475	199975	53.86	0.35	69727
2013	80003	28091	108094	11233	3276	14509	16973	139577	14984	58121	212682	56.32	0.31	66742
2014	84003	29496	113499	11795	3440	15235	16973	145707	16289	64256	226251	58.92	0.28	63900
2015	88203	30971	119174	12384	3612	15996	16973	152143	16363	67650	236155	60.47	0.25	60028
2016	92613	32519	125133	13004	3793	16796	16973	158902	16363	71032	246297	63.01	0.23	56345
2017	97244	34145	131309	13654	3982	17636	16973	165998	16363	74584	256945	65.73	0.21	52903
2018	102106	35852	137959	14336	4181	18518	16973	173450	16363	78313	268125	68.59	0.19	49684
2019	107212	37645	144857	15053	4391	19444	16973	181273	16363	82229	273865	71.59	0.17	46674
2020	112572	39527	152099	15806	4610	20416	16973	189488	16363	86340	292191	74.75	0.15	43856
2021	118201	41504	159704	16596	4841	21437	69862	251003	16363	90657	358023	91.59	0.14	48564
2022	124111	43579	167690	17426	5083	22509	69862	260060	16363	95190	371613	95.07	0.12	45179
2023	130316	45758	176074	18297	5337	23634	69862	269570	16363	99949	385882	98.72	0.11	42223
2024	136832	48046	184878	19212	5604	24816	69862	279556	16363	104947	400865	102.55	0.10	39476
2025	143674	50448	194122	20173	5884	26057	69862	290040	16363	110194	416597	106.57	0.09	36923
2026	150858	52970	203828	21181	6178	27359	69862	301049	16363	115704	433116	110.80	0.08	34548
2027	158400	55619	214019	22241	6487	28727	69862	312609	16363	121489	450460	115.24	0.07	32338
2028	166320	58400	224720	23353	6811	30164	69862	324746	16363	127564	468672	119.90	0.06	30281
2029	174636	61320	235956	24520	7152	31672	69862	337490	16363	133942	487794	124.79	0.06	28365
2030	183368	64386	247754	25746	7509	33256	69862	350872	16363	140639	507873	129.92	0.05	26579
2031	192537	67605	260142	27034	7885	34918	69862	364922	16363	147671	528955	135.32	0.05	24914
2032	202163	70985	273149	28385	8279	36664	69862	379675	16363	155054	551092	140.98	0.04	23361
2033	212272	74535	286806	29804	8693	38497	69862	395166	16363	162807	574335	146.93	0.04	21912
2034	222885	78261	301146	31295	9128	40422	69862	411431	16363	170947	598741	153.17	0.03	20559
2035	234030	82174	316204	32859	9584	42443	69862	428509	16363	179495	624367	159.73	0.03	19295
2036	245731	86283	332014	34502	10063	44566	69862	446442	16363	188470	651274	166.61	0.03	18114
2037	258018	90597	348615	36228	10566	46794	69862	465271	16363	197893	679526	173.84	0.03	17010
2038	270918	95127	366045	38039	11095	49134	69862	485041	16363	207788	709191	181.43	0.02	15977
2039	284464	99883	384348	39941	11649	51590	69862	505800	16363	218177	740340	189.39	0.02	15011
2040	298688	104878	403565	41938	12232	54170	69862	527597	16363	229086	773045	197.76	0.02	14107
TOTAL	5725458	2010369	7735827	803896	234470	1038366	1906430	10680623	579807	4001319	15261749			1964738

NOTES: SINKING FUND ENDS AFTER TENTH YEAR
AMORTIZATION OF NEW CHILLERS BEGINS BEFORE ELEVENTH YEAR
BASED ON $1303/TON FOR CHILLERS AFTER TENTH YEAR
AMORTIZATION TERM IS 25 YEARS

FIGURE 25
CALCULATION OF INITIAL COST ($ 000) SLOW CASE

COL.1 YEAR	COL.2 ENGINEERING COSTS MECH. & ELECTRIC	COL.3 ENV. STUDIES	COL.4 LEGAL	COL.5 CONTRACT	COL.6 CONTINGENCY	COL.7 HEAT EX.	COL.8 CUSTOMER CONN'S	COL.9 CUSTOMER ENG.	COL.10 15% TAXES	COL.11 TOTAL	COL.12 INTEREST MULTIPLIER	COL.13 TOTAL
1992	5000	1000	100	0	0	0	0	0	915	7015	2.59	18195.1
1993	1000	1000	100	0	0	0	0	0	315	2415	2.36	5694.4
1994	1000	1000	100	0	0	0	0	0	315	2415	2.14	5176.8
1995	1000	1000	100	0	0	0	0	0	315	2415	1.95	4706.2
1996	1000	1000	100	0	0	0	0	0	315	2415	1.77	4278.3
1997	1000	1000	100	0	0	0	0	0	315	2415	1.61	3889.4
1998	8000	0	100	0	0	0	0	0	1215	9315	1.46	13638.1
1999	8000	0	100	89000	8900	0	0	0	15900	121900	1.33	162248.9
2000	1500	0	100	93500	9350	0	0	0	15668	120118	1.21	145342.2
2001	1500	0	100	98000	9800	38800	124100	15000	43095	330395	1.10	363434.5
TOTAL	29000	6000	1000	280500	28050	38800	124100	15000	78367.5	600817.5		726603.8

ONTARIO HYDRO INCENTIVE FOR YEAR 2002 ($621/TON, 240747 TONS) 149391.0
NET INITIAL COST: 577212.8
COST OF INTERIM FINANCE: (726604-600818) 125786.3

FIGURE 27
COST OF LAKEWATER COOLING SLOW CASE

							HEAT EXCHANGERS		HEAT EX. AMORTIZED		ADMIN. COSTS $000		HYDRO INCENTIVES		NET COSTS			
COL.2 SYSTEM TONS	COL.3 MILLION TON-HOURS	COL.4 300 K-TON ENERGY ($ 000)	COL.5 PUMP WORK FACTOR	COL.6 ACTUAL ENERGY ($ 000)	COL.7 PLANT COST AMORTIZED ($ 000)	COL.8 TONS	COL.9 TOTAL NEW TONS	COL.10 COST/ NEW TON ($)	COL.11 ANNUAL COST $000	COL.12 TOTAL COST $000	COL.13 SALARIES	COL.14 REPAIRS, ETC.	COL.15 INCENTIVE $ PER TON	COL.16 TOTAL ($000)	COL.17 COL.6+7+ 12TO14-16 ($000)	COL.18 TOTAL CENTS/ TON-HR	COL.19 COST 10% INT FACTOR	COL.20 PRESEN WORTH ($000)
240747	313.69	4597	0.545	2506	58876	4024	4024	204	87	87	428	342	684	2753	59485	18.96	1.00	5948
244839	319.03	4827	0.567	2737	58876	4093	8117	214	93	180	449	359	718	2940	59661	18.70	0.90	5369
249002	324.45	5069	0.591	2996	58876	4162	12279	224	99	279	471	377	754	3139	59859	18.45	0.81	4848
253235	329.96	5322	0.613	3262	58876	4233	16512	236	106	384	495	396	792	3352	60061	18.20	0.73	4378
257540	335.57	5588	0.642	3588	58876	4305	20817	247	113	497	520	416	832	3580	60316	17.97	0.66	3957
261918	341.28	5868	0.670	3931	58876	4378	25195	260	121	618	546	437	873	3823	60584	17.75	0.59	3577
266371	347.08	6161	0.699	4307	58876	4453	29648	273	129	747	573	458	917	4082	60878	17.54	0.53	3235
270899	352.98	6469	0.729	4716	58876	4528	34176	287	138	884	602	481	963	4359	61200	17.34	0.48	2927
275504	358.98	6792	0.761	5169	58876	4605	38782	301	147	1031	632	505	1011	4655	61558	17.15	0.43	2649
280188	365.08	7132	0.802	5720	58876	4684	43465	316	157	1188	663	531	1061	4971	62007	16.98	0.39	2402
284951	371.29	7489	0.851	6373	58876	4763	48228	332	167	1355	696	557	1114	5308	62550	16.85	0.35	2181
289795	377.60	7863	0.900	7077	58876	4844	53073	348	179	1534	731	585	1170	5668	63135	16.72	0.31	1981
294722	384.02	8256	0.949	7835	58876	4927	57999	366	191	1725	768	614	1229	6053	63766	16.60	0.28	1800
299732	390.55	8669	0.999	8660	58876	5010	63009	384	204	1929	806	645	1290	6463	64453	16.50	0.25	1638
300000	390.90	9103	1.000	9103	58876	268	63278	403	11	1941	847	677	1355	363	71079	18.18	0.23	1626
300000	390.90	9558	1.000	9558	58876	0	63278	423	0	1941	889	711	1422	0	71974	18.41	0.21	1481
300000	390.90	10036	1.000	10036	58876	0	63278	444	0	1941	933	747	1493	0	72532	18.56	0.19	1344
300000	390.90	10537	1.000	10537	58876	0	63278	467	0	1941	980	784	1568	0	73118	18.70	0.17	1219
300000	390.90	11064	1.000	11064	58876	0	63278	490	0	1941	1029	823	1646	0	73733	18.86	0.15	1106
300000	390.90	11617	1.000	11617	58876	0	63278	515	0	1941	1080	864	1729	0	74379	19.03	0.14	1004
300000	390.90	12198	1.000	12198	58876	0	63278	540	0	1941	1135	908	1815	0	75057	19.20	0.12	912
300000	390.90	12808	1.000	12808	58876	0	63278	567	0	1941	1191	953	1906	0	75769	19.38	0.11	829
300000	390.90	13449	1.000	13449	58876	0	63278	596	0	1941	1251	1001	2001	0	76516	19.57	0.10	753
300000	390.90	14121	1.000	14121	58876	0	63278	625	0	1941	1313	1051	2101	0	77301	19.78	0.09	685
300000	390.90	14827	1.000	14827	58876	0	63278	657	0	1941	1379	1103	2206	0	78126	19.99	0.08	623
300000	390.90	15569	1.000	15569	58876	0	63278	690	0	1941	1448	1158	2317	0	78991	20.21	0.07	567
300000	390.90	16347	1.000	16347	58876	0	63278	724	0	1941	1520	1216	2433	0	79900	20.44	0.06	516
300000	390.90	17164	1.000	17164	58876	0	63278	760	0	1941	1596	1277	2554	0	80854	20.68	0.06	470
300000	390.90	18022	1.000	18022	58876	0	63278	798	0	1941	1676	1341	2682	0	81856	20.94	0.05	428
300000	390.90	18924	1.000	18924	58876	0	63278	838	0	1941	1760	1408	2816	0	82908	21.21	0.05	390
300000	390.90	19870	1.000	19870	58876	0	63278	880	0	1854	1848	1478	2957	0	83926	21.47	0.04	355
300000	390.90	20863	1.000	20863	58876	0	63278	924	0	1761	1940	1552	3105	0	84993	21.74	0.04	324
300000	390.90	21906	1.000	21906	58876	0	63278	970	0	1662	2037	1630	3260	0	86111	22.03	0.03	295
300000	390.90	23002	1.000	23002	58876	0	68278	1019	0	1556	2139	1711	3423	0	87284	22.33	0.03	269
300000	390.90	24152	1.000	24152	58876	0	63278	1070	0	1443	2246	1797	3594	0	88514	22.64	0.03	246
300000	390.90	25359	1.000	25359	58876	0	63278	1123	0	1323	2359	1887	3774	0	89803	22.97	0.03	224
300000	390.90	26627	1.000	26627	58876	0	63278	1179	0	1194	2476	1981	3962	0	91155	23.32	0.02	205
300000	390.90	27959	1.000	27959	58876	0	63278	1238	0	1056	2600	2080	4161	0	92571	23.68	0.02	187
300000	390.90	29357	1.000	29357	58876	0	63278	1300	0	909	2730	2184	4369	0	94057	24.06	0.02	171
	14684			503317	2296153						48785	39028		61510	2882017			63135

1. PUMP ENERGY IS NOT PROPORTIONAL TO SYSTEM TONS.
LARGER TONNAGES ARE PUMPED AT GREATER FRICTION FACTOR.
SEE FIGURE 10 FOR FRICTION CURVE.
2. FRICTION CURVE BASED ON 300000 TON SIZING

FIGURE 25
CALCULATION OF INITIAL COST ($ 000) FAST CASE

COL.1	COL.2	COL.3	COL.4	COL.5	COL.6	COL.7	COL.8	COL.9	COL.10	COL.11	COL.12	COL.13
	ENGINEERING COSTS											
YEAR	MECH. & ELECTRIC	ENV. STUDIES	LEGAL	CONTRACT	CONTINGENCY	HEAT EX.	CUSTOMER CONN'S	CUSTOMER ENG.	15% TAXES	TOTAL	INTEREST MULTIPLIER	TOTAL
1992	5000	1000	100	0	0	0	0	0	915	7015	1.77	12427.5
1993	1000	1000	100	0	0	0	0	0	315	2415	1.61	3889.4
1994	7000	0	100	0	0	0	0	0	1065	8165	1.46	11954.4
1995	7000	0	100	73000	7300	0	0	0	13110	100510	1.33	133778.8
1996	1500	0	100	77000	7700	0	0	0	12945	99245	1.21	120086.5
1997	1500	0	100	81000	8100	31500	102200	10000	35160	269560	1.10	296516.0
1998	0	0	0	0	0	0	0	0	0	0	1.00	0.0
TOTAL	23000	2000	600	231000	23100	31500	102200	10000	63510	486910		578652.5

ONTARIO HYDRO INCENTIVE FOR YEAR 1998 ($563/TON, 225049 TONS)		126702.0
NET INITIAL COST:		451950.5
COST OF INTERIM FINANCE:	(578653-486910)	91742.5

FIGURE 27

COST OF LAKEWATER COOLING FAST CASE

							HEAT EXCHANGERS			HEHT EX.AMOPTIZED		ADMIN. COSTS $000		HYDRO INCENTIVES		NET COSTS			
COL.1 YEAR	COL.2 SYSTEM TONS	COL.3 MILLION TON-HOURS	COL.4 300 K-TON ENERGY ($ 000)	COL.5 PUMP WORK FACTOR	COL.6 ACTUAL ENEPGY ($ 000)	COL.7 PLANT COST AMOPTIZED ($ 000)	COL.8 TONS	COL.9 TOTAL NEW TONS	COL.10 COST/ NEW TON ($)	COL.11 ANNUAL CUST $000	COL.12 TOTAL COST $000	COL.13 SALARIES	COL.14 REPAIPS, ETC.	COL.15 INCENTIVE $ PER TON	COL.16 INCENTIVE TOTAL ($000)	COL.17 COL.6+7+ 12TU14-16 ($000)	COL.18 TOTAL CENTS/ TON-HR	COL.19 COST 10% INT FACTOR	COL.20 PRESEN WORTH ($000)
1998	225049	293.24	3782	0.501	1895	46099	3762	3762	168	67	67	352	281	563	2117	46577	15.88		
1999	228875	298.22	3971	0.509	2021	46099	3825	7587	[illegible]	71	138	369	295	591	2261	46662	15.65	1.00	4666
2000	232765	303.29	4170	0.518	2160	46099	3890	11477	[illegible]	76	214	388	310	621	2414	46757	15.42	0.90	4206
2001	236722	308.45	4379	0.530	2321	46099	3957	15434	194	81	296	407	326	652	2578	46870	15.20	0.81	3796
2002	240747	313.69	4597	0.545	2506	46099	4024	19459	204	87	382	428	342	684	2753	47004	14.98	0.73	3426
2003	244839	319.03	4827	0.567	2737	46099	4093	23551	214	93	475	449	359	718	2940	47179	14.79	0.66	3095
2004	249002	324.45	5069	0.591	2996	46099	4162	27714	224	99	574	471	377	754	3139	47378	14.60	0.59	2797
2005	253235	329.96	5322	0.613	3262	46099	4233	31947	236	106	680	495	396	792	3352	47580	14.42	0.53	2528
2006	257540	335.57	5588	0.642	3588	46099	4305	36252	247	113	793	520	416	832	3580	47835	14.25	0.48	2287
2007	261918	341.28	5868	0.670	3931	46099	4378	40630	260	121	914	546	437	873	3823	48105	14.10	0.43	2070
2008	266371	347.08	6161	0.699	4307	46099	4453	45082	273	129	1042	573	458	917	4082	48397	13.94	0.39	1875
2009	270899	352.98	6469	0.729	4716	46099	4528	49611	287	138	1180	602	481	963	4359	48719	13.80	0.35	1698
2010	275504	358.98	6792	0.761	5169	46099	4605	54216	301	147	1327	632	505	1011	4655	49077	13.67	0.31	1540
2011	280188	365.08	7152	0.802	5720	46099	4684	58900	316	157	1484	663	531	1061	4971	49526	13.57	0.28	1398
2012	284951	371.29	7489	0.851	6373	46099	4763	63663	332	167	1651	696	557	1114	5308	50068	13.43	0.25	1272
2013	289795	377.60	7863	0.900	7077	46099	4844	68507	340	179	1830	731	585	1170	5668	50654	13.41	0.23	1158
2014	294722	384.02	8256	0.949	7835	46099	4927	73434	366	191	2021	768	614	1229	6053	51284	13.35	0.21	1055
2015	299732	390.55	8669	0.999	8660	46099	5010	78444	384	204	2225	806	645	1290	6465	51972	13.31	0.19	9631
2016	300000	390.90	9103	1.000	9103	46099	268	78712	403	11	2236	847	677	1355	363	58598	14.99	0.17	9773
2017	300000	390.90	9558	1.000	9558	46099	0	78712	423	0	2236	889	711	1422	0	59495	15.22	0.15	8930
2018	300000	390.90	10036	1.000	10036	46099	0	78712	444	0	2236	933	747	1493	0	60051	15.36	0.14	[illegible]
2019	300000	390.90	10537	1.000	10537	46099	0	78712	467	0	2236	980	784	1568	0	60637	15.51	0.12	[illegible]
2020	300000	390.90	11064	1.000	11064	46099	0	78712	490	0	2236	1029	823	1646	0	61252	15.67	0.11	6702
2021	300000	390.90	11617	1.000	11617	46099	0	78712	515	0	2236	1080	864	1729	0	61897	15.83	0.10	6095
2022	300000	390.90	12198	1.000	12198	46099	0	78712	540	0	2236	1135	908	1815	0	62576	16.01	0.09	5546
2023	300000	390.90	12808	1.000	12808	46099	0	78712	567	0	2236	1191	953	1906	0	63288	16.19	0.08	5040
2024	300000	390.90	13449	1.000	13449	46099	0	78712	596	0	2236	1251	1001	2001	0	64035	16.38	0.07	4597
2025	300000	390.90	14121	1.000	14121	46099	0	78712	625	0	2236	1313	1051	2101	0	64820	16.58	0.06	4188
2026	300000	390.90	14827	1.000	14827	46099	0	78712	657	0	2236	1379	1103	2206	0	65644	16.79	0.06	3817
2027	300000	390.90	15569	1.000	15569	46099	0	78712	690	0	2169	1448	1158	2317	0	66443	17.00	0.05	3477
2028	300000	390.90	16347	1.000	16347	46099	0	78712	724	0	2098	1520	1216	2433	0	67281	17.21	0.05	3169
2029	300000	390.90	17164	1.000	17164	46099	0	78712	760	0	2022	1596	1277	2554	0	68159	17.44	0.04	2889
2030	300000	390.90	18022	1.000	18022	46099	0	78712	798	0	1941	1676	1341	2682	0	69079	17.67	0.04	2636
2031	300000	390.90	18924	1.000	18924	46099	0	78712	838	0	1854	1760	1408	2816	0	70044	17.92	0.03	2405
2032	300000	390.90	19870	1.000	19870	46099	0	78712	880	0	1761	1848	1478	2957	0	71056	18.18	0.03	2196
2033	300000	390.90	20863	1.000	20863	46099	0	78712	924	0	1662	1940	1552	3105	0	72117	18.45	0.03	2006
2034	300000	390.90	21906	1.000	21906	46099	0	78712	970	0	1556	2037	1630	[illegible]	0	73229	18.73	0.03	1833
2035	300000	390.90	23002	1.000	23002	46099	0	78712	1019	0	1443	2139	1711	3423	0	74395	19.03	0.02	1676
2036	300000	390.90	24152	1.000	24152	46099	0	78712	1070	0	1323	2246	1797	3594	0	75617	19.34	0.02	1533
2037	300000	330.90	25359	1.000	25359	46099	0	78712	1123	0	1194	2359	1887	3774	0	76898	19.67	0.02	1403
2038	300000	390.90	26627	1.000	26627	46099	0	78712	1179	0	1056	2476	1981	[illegible]	0	78240	20.0.	0.02	1285
2039	300000	390.90	27959	1.000	27959	0	0	78712	1238	0	909	2600	2080	4161	0	33549	8.58	0.01	496
2040	300000	390.90	29357	1.000	29357	0	0	78712	1300	0	753	2730	2184	4369	0	35024	8.96	0.01	466
TOTAL		15295.82			507797	1797859						49580	39664		66503	2391823			[illegible]

NOTES1. PUMP ENERGY IS NOT PPOPORTIONAL TO SYSTEM TONS.
LAPGER TONNAGES APE PUMPED AT GREATER FRICTION FACTOP.
SEE FIGUPE 18 FOR FPICTION CURVE.

2. FRICTION CURVE BASED ON 300000 TON SIZING

FIGURE 25
CALCULATION OF INITIAL COST ($ 000) BASE CASE, WITH CUSTOMER SHORTFALL

COL.1 YEAR	COL.2 ENGINEERING COSTS MECH. & ELECTRIC	COL.3 ENGINEERING COSTS ENV. STUDIES	COL.4 LEGAL	COL.5 CONTRACT	COL.6 CONTINGENCY	COL.7 HEAT EX.	COL.8 CUSTOMER CONN'S	COL.9 CUSTOMER ENG.	COL.10 15% TAXES	COL.11 TOTAL	COL.12 INTEREST MULTIPLIER	COL.13 TOTAL
1992	5000	1000	100	0	0	0	0	0	915	7015	1.95	13670.3
1993	1000	1000	100	0	0	0	0	0	315	2415	1.77	4278.3
1994	1000	1000	100	0	0	0	0	0	315	2415	1.61	3889.4
1995	7000	0	100	0	0	0	0	0	1065	8165	1.46	11954.4
1996	7000	0	100	77000	7500	0	0	0	13740	105340	1.33	140207.5
1997	1500	0	100	81000	8000	0	0	0	13590	104190	1.21	126069.9
1998	1500	0	100	85000	8500	16750	107200	10000	34358	263408	1.10	289748.3
TOTAL	24000	3000	700	243000	24000	16750	107200	10000	64298	492948		589818.0

ONTARIO HYDRO INCENTIVE FOR YEAR 1999 ($591/TON, 112525 TONS) 66502.3
NET INITIAL COST: 523315.7
COST OF INTERIM FINANCE: (589818-492948) 96870.5

FIGURE 27

COST OF LAKEWATER COOLING BASE CASE, WITH CUSTOMER SHORTFALL slow connect

								HEAT EXCHANGERS		HEAT EX. AMORTIZED		ADMIN. COSTS $000		HYDRO INCENTIVES		NET COSTS			
COL.1 YEAR	COL.2 SYSTEM TONS	COL.3 MILLION TON-HOURS	COL.4 300 K-TON ENERGY ($ 000)	COL.5 PUMP WORK FACTOR	COL.6 ACTUAL ENERGY ($ 000)	COL.7 PLANT COST AMORTIZED ($ 000)	COL.8 TONS	COL.9 TOTAL NEW TONS	COL.10 COST/ NEW TON ($)	COL.11 ANNUAL COST $000	COL.12 TOTAL COST $000	COL.13 SALARIES	COL.14 REPAIRS, ETC.	COL.15 INCENTIVE $ PER TON	COL.16 TOTAL ($000)	COL.17 COL.6+7+ 12TO14-16 ($000)	COL.18 TOTAL CENTS/ TON-HR	COL.19 COST 10% INT FACTOR	COL.20 PRESEN WORTH ($000)
1999	114438	149.11	3971	0.509	2021	46364	1913	1913	176	6	36	369	295	591	1130	47956	32.16	1.00	4795
2000	116383	151.65	4170	0.518	2160	46364	1945	3858	185	38	74	388	310	621	1207	48089	31.71	0.90	4328
2001	118361	154.22	4379	0.530	2321	46364	1979	5836	194	41	114	407	326	652	1289	48243	31.28	0.81	3907
2002	120373	156.85	4597	0.545	2506	46364	2012	7849	204	43	158	428	342	684	1377	48421	30.87	0.73	3529
2003	122420	159.51	4827	0.567	2737	46364	2046	9895	214	46	204	449	359	718	1470	48644	30.50	0.66	3191
2004	186751	243.34	5069	0.591	2996	46364	64332	74227	224	1531	1735	471	377	754	48523	3421	1.41	0.59	202
2005	189926	247.47	5322	0.613	3262	46364	3175	77401	236	79	1814	495	396	792	2514	49818	20.13	0.53	2647
2006	193155	251.68	5588	0.642	3588	46364	3229	80630	247	85	1899	520	416	832	2685	50102	19.91	0.48	2396
2007	196438	255.96	5868	0.670	3931	46364	3284	83914	260	90	1989	546	437	873	2867	50400	19.69	0.43	2169
2008	199778	260.31	6161	0.699	4307	46364	3339	87253	273	97	2086	573	458	917	3062	50727	19.49	0.39	1965
2009	270893	352.98	6469	0.729	4716	46364	71121	158374	287	2160	4246	602	481	963	68464	-12055	-3.42	0.35	-420
2010	275504	358.98	6792	0.761	5169	46364	4605	162979	301	147	4393	632	505	1011	4655	52408	14.60	0.31	1644
2011	280188	365.08	7132	0.802	5720	46364	4684	167663	316	157	4550	663	531	1061	4971	52857	14.48	0.28	1492
2012	284951	371.29	7489	0.851	6373	46364	4763	172426	332	167	4717	696	557	1114	5508	53400	14.38	0.25	1357
2013	289795	377.60	7863	0.900	7077	46364	4844	177270	348	179	4896	731	585	1170	5668	53985	14.30	0.23	1235
2014	294722	384.02	8256	0.949	7835	46364	4927	182197	366	191	5087	768	614	1229	6053	54616	14.22	0.21	1124
2015	299732	390.55	8669	0.999	8660	46364	5010	187207	384	204	5291	806	645	1290	6463	55303	14.16	0.19	1024
2016	300000	390.90	9103	1.000	9103	46364	268	187475	403	11	5302	847	677	1355	563	61930	15.84	0.17	1032
2017	300000	390.90	9558	1.000	9558	46364	0	187475	423	0	5302	889	711	1422	0	62824	16.07	0.15	9430
2018	300000	390.90	10036	1.000	10036	46364	0	187475	444	0	5302	933	747	1493	0	63382	16.21	0.14	856
2019	300000	390.90	10537	1.000	10537	46364	0	187475	467	0	5302	980	784	1568	0	63968	16.36	0.12	777
2020	300000	390.90	11064	1.000	11064	46364	0	187475	490	0	5302	1029	823	1646	0	64583	16.52	0.11	706
2021	300000	390.90	11617	1.000	11617	46364	0	187475	515	0	5302	1080	864	1729	0	65229	16.69	0.10	642
2022	300000	390.90	12198	1.000	12198	46364	0	187475	540	0	5302	1135	908	1815	0	65907	16.86	0.09	584
2023	300000	390.90	12808	1.000	12808	46364	0	187475	567	0	5302	1191	953	1906	0	66619	17.04	0.08	5314
2024	300000	390.90	13449	1.000	13449	46364	0	187475	596	0	5302	1251	1001	2001	0	67367	17.25	0.07	485
2025	300000	390.90	14121	1.000	14121	46364	0	187475	625	0	5302	1313	1051	2101	0	68152	17.45	0.06	440
2026	300000	390.90	14827	1.000	14827	46364	0	187475	657	0	5302	1379	1103	2206	0	68976	17.65	0.06	4011
2027	300000	390.90	15569	1.000	15569	46364	0	187475	690	0	5302	1448	1158	2317	0	69841	17.87	0.05	365
2028	300000	390.90	16347	1.000	16347	46364	0	187475	724	0	5267	1520	1216	2433	0	70715	18.09	0.05	3331
2029	300000	390.90	17164	1.000	17164	46364	-0	187475	760	0	5228	1596	1277	2554	0	71631	18.32	0.04	3037
2030	300000	390.90	18022	1.000	18022	46364	0	187475	798	0	5188	1676	1341	2682	0	72592	18.57	0.04	2770
2031	300000	390.90	18924	1.000	18924	46364	0	187475	838	0	5144	1760	1408	2816	0	73600	18.83	0.03	2527
2032	300000	390.90	19870	1.000	19870	46364	0	187475	880	0	5098	1848	1478	2957	0	74659	19.10	0.03	2307
2033	300000	390.90	20863	1.000	20863	46364	0	187475	924	0	3567	1940	1552	3105	0	74288	19.00	0.03	2066
2034	300000	390.90	21906	1.000	21906	46364	0	187475	970	0	3498	2037	1630	3260	0	75426	19.30	0.03	1888
2035	300000	390.90	23002	1.000	23002	46364	0	187475	1019	0	3403	2139	1711	3423	0	76620	19.60	0.02	172
2036	300000	390.90	24152	1.000	24152	46364	0	187475	1070	0	3313	2246	1797	3594	0	77872	19.92	0.02	1579
2037	300000	390.90	25359	1.000	25359	46364	0	187475	1123	0	3216	2359	1887	3774	0	79185	20.26	0.02	144
2038	300000	390.90	26627	1.000	26627	46364	0	187475	1179	0	1056	2476	1981	3962	0	78506	20.08	0.02	128
2039	300000	390.90	27959	1.000	27959	46364	0	187475	1238	0	909	2600	2080	4161	0	79913	20.44	0.01	1181
2040	300000	390.90	29357	1.000	29357	0	0	187475	1300	0	753	2730	2184	4369	0	35024	8.46	0.01	466
TOTAL		14254.01			507797	1854576						49580	39664		166939	2437189			421226

NOTES1. PUMP ENERGY IS NOT PROPORTIONAL TO SYSTEM TONS.
LARGER TONNAGES ARE PUMPED AT GREATER FRICTION FACTOR.
SEE FIGURE 18 FOR FRICTION CURVE.
2. FRICTION CURVE BASED ON 300000 TON SIZING

FIGURE 23

OPERATING COST OF CUSTOMERS' ORIGINAL ON-SITE COOLING PLANT

ALL AMOUNTS IN $000

COL.1	COL.2	COL.3	COL.4	COL.5	COL.6	COL.7	COL.8	COL.9	COL.10	COL.11	COL.12	COL.13	COL.14	COL.15
	ELECTRICITY COSTS			SERVICING COSTS					ADDED CHILLER CAPACITY COSTS $000				PRESENT WORTH FOR YEAR	
YEAR	CENTRAL (160,000 TONS)	COMP'T (40,000 TONS)	80/20 BLEND TOTAL	CENTRAL	COMP'T	80/20 BLEND TOTAL	AMORTIZED ORIGINAL 200 KTONS @ 10.6%	INITIAL SYSTEM COST	AMORTIZED CAPACITY	OPERATING COSTS	NET COST SUM OF COLS. 9 TO 11	CENTS PER TON-HP	10% FACTOR	PW ($000)
1991	25179	8765	33944	3840	1120	4960	16973	55877	288	662	56827	28.41		
1992	26438	9203	35641	4032	1176	5208	16973	57822	596	1402	59821	29.41		
1993	27760	9663	37423	4234	1235	5468	16973	59865	925	2227	63017	30.46		
1994	29148	10147	39294	4445	1297	5742	16973	62009	1276	3145	66430	31.58		
1995	30605	10654	41259	4668	1361	6029	16973	64261	1651	4163	70075	32.75		
1996	32135	11187	43322	4901	1429	6330	16973	66625	2051	5290	73967	33.99		
1997	33742	11746	45488	5146	1501	6647	16973	69108	2479	6556	78123	35.30		
1998	35429	12333	47763	5403	1576	6979	16973	71715	2935	7911	82562	36.69		
1999	37201	12950	50151	5673	1655	7328	16973	74452	3423	9426	87301	38.14	1.00	87301
2000	39061	13597	52658	5957	1737	7695	16973	77326	3943	11093	92362	39.68	0.90	83126
2001	41014	14277	55291	6255	1824	8079	16973	80344	4499	12924	97767	41.30	0.81	79191
2002	43065	14991	58056	6568	1916	8483	16973	83512	5093	14933	103538	43.01	0.73	75479
2003	45218	15741	60959	6896	2011	8907	16973	86839	5727	17135	109701	44.81	0.66	71975
2004	47479	16528	64006	7241	2112	9353	16973	90332	6404	19546	116282	46.70	0.59	68663
2005	49853	17354	67207	7603	2218	9820	16973	94000	7126	22183	123310	48.69	0.53	65532
2006	52345	18222	70567	7983	2328	10311	16973	97852	7898	25065	130815	50.79	0.48	62560
2007	54963	19133	74095	8382	2445	10827	16973	101896	8722	28211	138829	53.00	0.43	59761
2008	57711	20090	77800	8801	2567	11368	16973	106142	9605	31642	147386	55.33	0.39	57101
2009	60596	21094	81690	9241	2695	11937	16973	110600	10542	35383	156525	57.78	0.35	54577
2010	63626	22149	85775	9703	2830	12534	16973	115281	11546	39456	166284	60.36	0.31	52182
2011	66807	23256	90064	10189	2972	13160	16973	120197	12618	43890	176704	63.07	0.28	49907
2012	70140	24419	94567	10698	3120	13818	16973	125358	13762	48712	187832	65.92	0.25	47744
2013	73655	25640	99295	11233	3276	14509	16973	130777	14984	53954	199716	68.92	0.23	45689
2014	77338	26922	104260	11795	3440	15235	16973	136468	16289	59648	212405	72.07	0.21	43752
2015	81205	28268	109473	12384	3612	15996	16973	142442	16363	62799	221604	73.93	0.19	41064
2016	85265	29681	114946	13004	3793	16796	16973	148716	16363	65939	231017	77.01	0.17	38527
2017	89528	31165	120694	13654	3982	17636	16973	155303	16363	69256	240901	80.50	0.15	36150
2018	94005	32724	126728	14336	4181	18518	16973	162219	16363	72698	251280	83.76	0.14	33441
2019	98705	34360	133065	15053	4391	19444	16973	169482	16363	76333	262177	87.39	0.12	31875
2020	103640	36078	139718	15806	4610	20416	16973	177107	16363	80149	273619	91.21	0.11	29959
2021	108822	37882	146704	16596	4841	21437	69862	238003	16363	84157	338522	112.84	0.10	33337
2022	114263	39776	154039	17426	5083	22509	69862	246410	16363	88365	351137	117.05	0.09	31121
2023	119976	41765	161741	18297	5337	23634	69862	255237	16363	92783	364383	121.46	0.08	29066
2024	125975	43853	169828	19212	5604	24816	69862	264506	16363	97422	378291	126.10	0.07	27157
2025	132274	46046	178320	20173	5884	26057	69862	274238	16363	102293	392894	130.96	0.06	25385
2026	138888	48348	187236	21181	6178	27359	69862	284457	16363	107408	408227	136.08	0.06	23738
2027	145832	50765	196597	22241	6487	28727	69862	295187	16363	112778	424328	141.44	0.05	22207
2028	153124	53304	206427	23353	6811	30164	69862	306453	16363	118417	441233	147.08	0.05	20783
2029	160780	55969	216749	24520	7152	31672	69862	318283	16363	124338	458983	152.99	0.04	19457
2030	168819	58767	227586	25746	7509	33256	69862	330704	16363	130555	477621	159.21	0.04	18222
2031	177260	61706	238965	27034	7885	34918	69862	343746	16363	137083	497191	165.73	0.03	17072
2032	186123	64791	250914	28385	8279	36664	69862	357440	16363	143937	517739	172.58	0.03	16000
2033	195429	68030	263459	29804	8693	38497	69862	371819	16363	151134	539315	179.77	0.03	15000
2034	205200	71432	276632	31295	9128	40422	69862	386917	16363	158690	561969	187.32	0.03	14067
2035	215460	75003	290464	32859	9584	42443	69862	402769	16363	166625	585757	195.25	0.02	13196
2036	226234	78754	304987	34502	10063	44566	69862	419415	16363	174956	610733	203.58	0.02	12383
2037	237545	82691	320236	36228	10566	46794	69862	436892	16363	183704	636959	212.32	0.02	11623
2038	249422	86826	336248	38039	11095	49134	69862	455244	16363	192889	664495	221.50	0.02	10913
2039	261894	91167	353061	39941	11649	51590	69862	474513	16363	202534	693409	231.14	0.01	10249
2040	274988	95725	370714	41938	12232	54170	69862	494746	16363	212660	723768	241.26	0.01	9628
TOTAL	5271173	1834935	7106108	803896	234470	1038366	1906430	10050904	579807	3714421	14345132 550822 13,794310			1596639

NOTES: SINKING FUND ENDS AFTER TENTH YEAR
AMORTIZATION OF NEW CHILLERS BEGINS BEFORE ELEVENTH YEAR
BASED ON $1303/TON FOR CHILLERS AFTER TENTH YEAR
AMORTIZATION TERM IS 25 YEARS
BASED ON 1000 FULL-LOAD HOURS PER YEAR

FIGURE 27

COST OF LAKEWATER COOLING BASED ON 1000 FULL LOAD HOURS PER YEAR

							HEAT EXCHANGEPS		HEAT EX.AMORTIZED			ADMIN. COSTS $000		HYDRO INCENTIVES		NET COSTS			
COL.1 YEAR	COL.2 SYSTEM TONS	COL.3 MILLION TON-HOURS	COL.4 300 K-TON ENERGY ($ 000)	COL.5 PUMP WORK FACTOR	COL.6 ACTUAL ENERGY ($ 000)	COL.7 PLANT COST AMORTIZED ($ 000)	COL.8 TONS	COL.9 TOTAL NEW TONS	COL.10 COST/ NEW TON ($)	COL.11 ANNUAL COST $000	COL.12 TOTAL COST $000	COL.13 SALARIES	COL.14 REPAIRS, ETC.	COL.15 INCENTIVE $ PER TON	COL.16 TOTAL ($000)	COL.17 COL.6+7+ 12TO14-16 ($000)	COL:18 TOTAL CENTS/ TON-HR	COL.19 COST 10% INT FACTOR	COL.20 PRESEN WORTH ($000)
1999	228875	228.88	3971	0.509	2021	48526	3825	3825	176	71	71	369	295	591	2261	49022	21.42	1.00	4902
2000	232765	232.77	4170	0.518	2160	48526	3890	7716	185	76	147	388	310	621	2414	49117	21.10	0.90	4420
2001	236722	236.73	4379	0.530	2321	48526	3957	11673	194	81	229	407	326	652	2578	49230	20.80	0.81	3987
2002	240747	240.75	4597	0.545	2506	48526	4024	15697	204	87	316	428	342	684	2753	49363	20.50	0.73	3598
2003	244839	244.84	4827	0.567	2737	48526	4093	19790	214	93	408	449	359	718	2940	49539	20.23	0.66	3250
2004	249002	249.01	5069	0.591	2996	48526	4162	23952	224	99	507	471	377	754	3139	49738	19.97	0.59	2937
2005	253235	253.24	5322	0.613	3262	48526	4233	28185	236	106	613	495	396	792	3352	49940	19.72	0.53	2654
2006	257540	257.54	5588	0.642	3588	48526	4305	32490	247	113	726	520	416	832	3580	50195	19.49	0.48	2400
2007	261918	261.92	5868	0.670	3931	48526	4378	36868	260	121	847	546	437	873	3823	50463	19.27	0.43	2172
2008	266371	266.38	6161	0.699	4307	48526	4453	41321	273	129	976	573	458	917	4082	50757	19.05	0.39	1966
2009	270899	270.90	6469	0.729	4716	48526	4528	45849	287	138	1113	602	481	963	4359	51078	18.85	0.35	1781
2010	275504	275.51	6792	0.761	5169	48526	4605	50455	301	147	1260	632	505	1011	4655	51437	18.67	0.31	1614
2011	280188	280.19	7132	0.802	5720	48526	4684	55138	316	157	1417	663	531	1061	4971	51886	18.52	0.28	1465
2012	284951	284.96	7489	0.851	6373	48526	4763	59901	332	167	1584	696	557	1114	5308	52428	18.40	0.25	1332
2013	289795	289.80	7863	0.900	7077	48526	4844	64745	348	179	1763	731	585	1170	5668	53014	18.29	0.23	121
2014	294722	294.73	8256	0.949	7835	48526	4927	69672	366	191	1954	768	614	1229	6053	53644	18.20	0.21	1104
2015	299732	299.74	8669	0.999	8660	48526	5010	74682	384	204	2158	806	645	1290	6463	54332	18.13	0.19	1006
2016	300000	300.01	9103	1.000	9103	48526	268	74950	403	11	2169	847	677	1355	363	60958	20.32	0.17	1016
2017	300000	300.01	9558	1.000	9558	48526	0	74950	423	0	2169	889	711	1422	0	61853	20.62	0.15	928
2018	300000	300.01	10036	1.000	10036	48526	0	74950	444	0	2169	933	747	1493	0	62411	20.80	0.14	843
2019	300000	300.01	10537	1.000	10537	48526	0	74950	467	0	2169	980	784	1568	0	62996	21.00	0.12	765
2020	300000	300.01	11064	1.000	11064	48526	0	74950	490	0	2169	1029	823	1646	0	63611	21.20	0.11	696
2021	300000	300.01	11617	1.000	11617	48526	0	74950	515	0	2169	1080	864	1729	0	64257	21.42	0.10	632
2022	300000	300.01	12198	1.000	12198	48526	0	74950	540	0	2169	1135	908	1815	0	64935	21.64	0.09	575
2023	300000	300.01	12808	1.000	12808	48526	0	74950	567	0	2169	1191	953	1906	0	65647	21.88	0.08	523
2024	300000	300.01	13449	1.000	13449	48526	0	74950	596	0	2169	1251	1001	2001	0	66395	22.13	0.07	476
2025	300000	300.01	14121	1.000	14121	48526	0	74950	625	0	2169	1313	1051	2101	0	67180	22.39	0.06	4341
2026	300000	300.01	14827	1.000	14827	48526	0	74950	657	0	2169	1379	1103	2206	0	68004	22.67	0.06	3954
2027	300000	300.01	15569	1.000	15569	48526	0	74950	690	0	2169	1448	1158	2317	0	68870	22.96	0.05	3604
2028	300000	300.01	16347	1.000	16347	48526	0	74950	724	0	2098	1520	1216	2433	0	69707	23.24	0.05	326
2029	300000	300.01	17164	1.000	17164	48526	0	74950	760	0	2022	1596	1277	2554	0	70585	23.53	0.04	299
2030	300000	300.01	18022	1.000	18022	48526	0	74950	798	0	1941	1676	1341	2682	0	71506	23.83	0.04	272
2031	300000	300.01	18924	1.000	18924	48526	0	74950	838	0	1854	1760	1408	2816	0	72471	24.16	0.03	248
2032	300000	300.01	19870	1.000	19870	48526	0	74950	880	0	1761	1848	1478	2957	0	73483	24.49	0.03	2271
2033	300000	300.01	20863	1.000	20863	48526	0	74950	924	0	1662	1940	1552	3105	0	74544	24.85	0.03	207
2034	300000	300.01	21906	1.000	21906	48526	0	74950	970	0	1556	2037	1630	3260	0	75656	25.22	0.03	1894
2035	300000	300.01	23002	1.000	23002	48526	0	74950	1019	0	1443	2139	1711	3423	0	76821	25.61	0.02	1731
2036	300000	300.01	24152	1.000	24152	48526	0	74950	1070	0	1323	2246	1797	3594	0	78043	26.01	0.02	158
2037	300000	300.01	25359	1.000	25359	48526	0	74950	1123	0	1194	2359	1887	3774	0	79324	26.44	0.02	1448
2038	300000	300.01	26627	1.000	26627	48526	0	74950	1179	0	1056	2476	1981	3962	0	80667	26.89	0.02	1325
2039	300000	300.01	27959	1.000	27959	48526	0	74950	1238	0	909	2600	2080	4161	0	82074	27.36	0.01	1213
2040	300000	300.01	29357	1.000	29357	0	0	74950	1300	0	753	2730	2184	4369	0	35024	11.67	0.01	466
TOTAL		11739.16			507797	1941026						49580	39664		66503	2533186			471027

NOTES1. PUMP ENERGY IS NOT PROPORTIONAL TO SYSTEM TONS.
LARGLR TONNAGES ARE PUMPED AT GREATER FRICTION FACTOR.
SEE FIGURE 18 FOR FRICTION CURVE.
2. FRICTION CURVE BASED ON 300000 TON SIZING

FIGURE 25
CALCULATION OF INITIAL COST ($ 000) BASE CASE, WITH COST OVERRUNS

COL.1	COL.2	COL.3	COL.4	COL.5	COL.6	COL.7	COL.8	COL.9	COL.10	COL.11	COL.12	COL.13
	ENGINEERING COSTS											
YEAR	MECH. & ELECTRIC	ENV. STUDIES	LEGAL	CONTRACT	CONTINGENCY	HEAT EX.	CUSTOMER CONN'S	CUSTOMER ENG.	15% TAXES	TOTAL	INTEREST MULTIPLIER	TOTAL
1992	5000	1000	100	0	0	0	0	0	915	7015	1.95	13670.3
1993	1000	1000	100	0	0	0	0	0	315	2415	1.77	4278.3
1994	1000	1000	100	0	0	0	0	0	315	2415	1.61	3889.4
1995	7000	0	100	0	0	0	0	0	1065	8165	1.46	11954.4
1996	7000	0	100	88550	8500	0	0	0	15623	119773	1.33	159417.2
1997	1500	0	100	93150	9000	0	0	0	15563	119313	1.21	144368.1
1998	1500	0	100	97750	10000	33500	134000	10000	43027	329877	1.10	362865.2
TOTAL	24000	3000	700	279450	27500	33500	134000	10000	76823	588973		700442.9

ONTARIO HYDRO INCENTIVE FOR YEAR 1999 ($591/TON, 228875 TONS)		135265.0
NET INITIAL COST:		565177.9
COST OF INTERIM FINANCE:	(700443-588973)	111470.4

FIGURE 27
COST OF LAKEWATER COOLING BASE CASE, WITH COST OVERRUNS

								HEAT EXCHANGERS		HEAT EX. AMORTIZED		ADMIN. COSTS $000		HYDRO INCENTIVES		NET COSTS			
COL.1 YEAR	COL.2 SYSTEM TONS	COL.3 MILLION TON-HOURS	COL.4 300 K-TON ENERGY ($ 000)	COL.5 PUMP WORK FACTOR	COL.6 ACTUAL ENERGY ($ 000)	COL.7 PLANT COST AMORTIZED ($ 000)	COL.8 TONS	COL.9 TOTAL NEW TONS	COL.10 COST/ NEW TON ($)	COL.11 ANNUAL COST $000	COL.12 TOTAL COST $000	COL.13 SALARIES	COL.14 REPAIRS, ETC.	COL.15 INCENTIVE $ PER TON	COL.16 TOTAL ($000)	COL.17 COL.6+7+ 12TO14-16 ($000)	COL.18 TOTAL CENTS/ TON-HR	COL.19 COST 10% INT FACTOR	COL.20 PRESENT WORTH ($000)
1999	228875	298.22	3971	0.509	2021	57648	3825	3825	176	71	71	369	295	591	2261	58145	19.50	1.00	58145
2000	232765	303.29	4170	0.518	2160	57648	3890	7716	185	76	147	388	310	621	2414	58240	19.20	0.90	52416
2001	236722	308.45	4379	0.530	2321	57648	3957	11673	194	81	229	407	326	652	2578	58352	18.92	0.81	47265
2002	240747	313.69	4597	0.545	2506	57648	4024	15697	204	87	316	428	342	684	2753	58486	18.64	0.73	42636
2003	244839	319.03	4827	0.567	2737	57648	4093	19790	214	93	408	449	359	718	2940	58662	18.39	0.66	38488
2004	249002	324.45	5069	0.591	2996	57648	4162	23952	224	99	507	471	377	754	3139	58860	18.14	0.59	34756
2005	253255	329.96	5322	0.613	3262	57648	4233	28185	236	106	613	495	396	792	3352	59062	17.90	0.53	31388
2006	257540	335.57	5588	0.642	3588	57648	4305	32490	247	113	726	520	416	832	3580	59318	17.68	0.48	28371
2007	261918	341.28	5868	0.670	3931	57648	4378	36868	260	121	847	546	437	873	3823	59586	17.46	0.43	25650
2008	266371	347.08	6161	0.699	4307	57648	4453	41321	273	129	976	573	458	917	4082	59879	17.25	0.39	23199
2009	270899	352.98	6469	0.729	4716	57648	4528	45849	287	138	1113	602	481	963	4359	60201	17.06	0.35	20991
2010	275504	358.98	6792	0.761	5169	57648	4605	50455	301	147	1260	632	505	1011	4655	60559	16.87	0.31	19004
2011	280188	365.08	7132	0.802	5720	57648	4684	55138	316	157	1417	663	531	1061	4971	61008	16.71	0.28	17230
2012	284951	371.29	7489	0.851	6373	57648	4763	59901	332	167	1584	696	557	1114	5308	61551	16.58	0.25	15645
2013	289795	377.60	7863	0.900	7077	57648	4844	64745	348	179	1763	731	565	1170	5668	62136	16.46	0.23	14215
2014	294722	384.02	8256	0.949	7835	57648	4927	69672	366	191	1954	768	614	1229	6053	62767	16.34	0.21	12923
2015	299732	390.55	8669	0.999	8660	57648	5010	74682	384	204	2158	806	645	1290	6463	63454	16.25	0.19	11758
2016	300000	390.90	9103	1.000	9103	57648	268	74950	403	11	2169	847	677	1355	363	70081	17.93	0.17	11687
2017	300000	390.90	9558	1.000	9558	57648	0	74950	423	0	2169	889	711	1422	0	70975	18.16	0.15	10653
2018	300000	390.90	10036	1.000	10036	57648	0	74950	444	0	2169	933	747	1493	0	71533	18.30	0.14	9663
2019	300000	390.90	10537	1.000	10537	57648	0	74950	467	0	2169	980	784	1568	0	72119	18.45	0.12	8768
2020	300000	390.90	11064	1.000	11064	57648	0	74950	490	0	2169	1029	823	1646	0	72734	18.61	0.11	7958
2021	300000	390.90	11617	1.000	11617	57648	0	74950	515	0	2169	1080	864	1729	0	73380	18.77	0.10	7226
2022	300000	390.90	12198	1.000	12198	57648	0	74950	540	0	2169	1135	908	1815	0	74058	18.95	0.09	6564
2023	300000	390.90	12808	1.000	12808	57648	0	74950	567	0	2169	1191	953	1906	0	74770	19.13	0.08	5964
2024	300000	390.90	13449	1.000	13449	57648	0	74950	596	0	2169	1251	1001	2001	0	75518	19.32	0.07	5421
2025	300000	390.90	14121	1.000	14121	57648	0	74950	625	0	2169	1313	1051	2101	0	76303	19.52	0.06	4930
2026	300000	390.90	14827	1.000	14827	57648	0	74950	657	0	2169	1379	1103	2206	0	77127	19.73	0.06	4485
2027	300000	390.90	15569	1.000	15569	57648	0	74950	690	0	2169	1448	1158	2317	0	77992	19.95	0.05	4082
2028	300000	390.90	16347	1.000	16347	57648	0	74950	724	0	2098	1520	1216	2433	0	78830	20.17	0.05	3713
2029	300000	390.90	17164	1.000	17164	57648	0	74950	760	0	2022	1596	1277	2554	0	79708	20.39	0.04	3379
2030	300000	390.90	18022	1.000	18022	57648	0	74950	798	0	1941	1676	1341	2682	0	80628	20.63	0.04	3076
2031	300000	390.90	18924	1.000	18924	57648	0	74950	838	0	1854	1760	1408	2816	0	81593	20.87	0.03	2802
2032	300000	390.90	19870	1.000	19870	57648	0	74950	880	0	1761	1848	1478	2957	0	82605	21.13	0.03	2553
2033	300000	390.90	20863	1.000	20863	57648	0	74950	924	0	1662	1940	1552	3105	0	83666	21.40	0.03	2327
2034	300000	390.90	21906	1.000	21906	57648	0	74950	970	0	1556	2037	1630	3260	0	84778	21.69	0.03	2122
2035	300000	390.90	23002	1.000	23002	57648	0	74950	1019	0	1443	2139	1711	3423	0	85944	21.99	0.02	1936
2036	300000	390.90	24152	1.000	24152	57648	0	74950	1070	0	1323	2246	1797	3594	0	87166	22.30	0.02	1767
2037	300000	390.90	25359	1.000	25359	57648	0	74950	1123	0	1194	2359	1887	3774	0	88447	22.63	0.02	1614
2038	300000	390.90	26627	1.000	26627	57648	0	74950	1179	0	1056	2476	1981	3962	0	89790	22.97	0.02	1475
2039	300000	390.90	27959	1.000	27959	57648	0	74950	1238	0	909	2600	2080	4161	0	91197	23.33	0.01	1348
2040	300000	390.90	29357	1.000	29357	0	0	74950	1300	0	753	2730	2184	4369	0	35024	8.96	0.01	466
TOTAL		15295.82			507797	2305926						49580	39664		66503	2898086			551916

NOTES1. PUMP ENERGY IS NOT PROPORTIONAL TO SYSTEM TONS.
LARGER TONNAGES ARE PUMPED AT GREATER FRICTION FACTOR.
SEE FIGURE 18 FOR FRICTION CURVE.
2. FRICTION CURVE BASED ON 300000 TON SIZING

APPENDIX H

Sayers & Associates Limited Budget

SAYERS & ASSOCIATES LIMITED
MECHANICAL CONTRACTORS
2240 ARGENTIA ROAD MISSISSAUGA ONTARIO L5N 2X6
TELEPHONE (416) 821-4500 FAX (416) 821-0664

RECEIVED
MAY 8 1991

May 6, 1991

Engineering Interface Limited
2 Sheppard Avenue East
Suite 200
North York, Ontario
M2N 5Y7

Attention: Mr. R.T. Tamblyn

Dear Sir,

SUBJECT: TORONTO FREE COOLING (BUDGET PRICE)

We are pleased to submit herewith, our budget price for the mechanical work at the above noted project in accordance with our discussions and site tour with Bob Moore for the amount of **Three Million, Five Hundred and Sixty Thousand Dollars.............$(3,560,000.00).**

The above price includes taxes as applicable at this date however, does not include G.S.T.

Price includes for the following; all piping as shown on sketches (from valve's in valve chamber by others) also price based on normal working hours and current prices.

We trust the foregoing is satisfactory.

Yours truly,

SAYERS & ASSOCIATES LIMITED

B Moore

Bob Moore
Project Manager

BM:sc

APPENDIX I

Report on Temperature Gain in Lakewater Supply

by

Dr. Douglas Baines

Heating of Water in FREECOOL System

by

W. Douglas Baines, Ph.D., P.Eng.

prepared for R.T. Tamblyn

Engineering Interface Limited.

Estimated temperature rise in the water flowing in the system sketched on your FAX dated May 3, 1991.

Temperature rise in °C.

Discharge	600,000 USgpm	60,000 USgpm
Through intake	0.07	0.05
Through pumps	0.07	0.01
Through supply line	0.075	0.05
Through branch line 1200 ft (518.5 m) long		
- in soil	0.07	0.02
- in basement	0.12	1.2
at 30°C (1½ in fibreglass insulation) } for this case the temperature rise is proportional to the length in a basement		
TOTAL	0.335	1.31

App I.

APPENDIX J

Report on Selection of Pipe and Protection Against Pipe Corrosion

by

Alan Stevens

ENVIRONMENTAL STUDIES REPORT
FOR THE
DEEP LAKE WATER COOLING
INVESTIGATION GROUP

Prepared for

Deep Lake Water Cooling Investigation Group
Toronto District Heating Corporation

By

MacViro Consultants Inc.
7270 Woodbine Ave., 3rd Floor
Markham, Ontario L3R 4B9

May 1991
#3144

MacViro

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1.0 INTRODUCTION

On March 15, 1991, the Deep Lake Water Cooling Investigation Group authorized MacViro Consultants Inc. to study, on a preliminary basis, the effects of the deep lake water cooling concept on the environment. This report presents the results of these preliminary studies and provides some insight into the significance of the effects that the concept may have on the environment.

The scope of this work was limited to specific study areas that were identified by the Investigation Group as being of particular interest. Emphasis was placed on several of the more complex environmental issues so that their significance could be quantified to some degree, permitting more meaningful discussions during the Charrette. These special study areas included extensive modelling of the water in the Toronto Harbour to determine the significance of the effects of the cooling water discharge on the temperature and water quality in the Harbour, as well as the Don River; and modelling of the air shed to determine whether temperature changes in the air and/or harbour water, as a result of the deep water cooling concept, had the potential to significantly impact the dispersion patterns and, therefore, the quality of the air over the downtown area. Other environmental aspects covered by this report include:

- the potential air emission reduction/resource conservation benefits associated with reduction of the demand for electricity as a result of implementing deep lake water cooling in lieu of the presently utilized electrically powered chiller systems with their associated roof mounted evaporative cooling systems;

- the potential for depletion of the historically available cold water supply in the deep water zones of Lake Ontario, and the potential for the intake associated with the deep lake water cooling concept to negatively impact the fish population, including larval fish and eggs, in the immediate area of the intake;

- the potential for positive or negative impacts associated with disposal of excavated material from construction of the deep water intake tunnel, pump house, and distribution system tunnels, together with review of possible alternate uses of the material.

In addition to the above, this report provides an overview of the environmental assessment process and other approvals that will have to be obtained if the deep lake water cooling concept is pursued further. Such approvals will require extensive studies to determine more precisely the potential benefits and the significance of any negative impacts that the deep lake water cooling concept will have on the environment. The final section of this report includes a brief discussion of several other environmentally related issues that were identified by the Investigation Group as having potential benefits or negative impacts, or that were noted (during the consultation process undertaken by the Canadian Urban Institute) by other interested parties as representing, in their minds, possible areas of concern with the concept.

One environmentally related aspect that is not discussed in this report involves the study of the potential impact the deep water cooling concept may have on the shoreline ecology. This important area has been studied and reported on by Pollution Probe.

The work presented in this report is based primarily on the lakewater cooling system position paper prepared by Engineering Interface. This position paper, supported by the Proctor & Redfern Report entitled "Civil Engineering Works for the Downtown Toronto Deep Lake Water Cooling System", provides technical background on the intake, pump house and north-south discharge tunnels associated with the concept.

2.0 THE ENVIRONMENTAL ASSESSMENT PROCESS AND APPROVALS REQUIREMENTS

2.1 General

The Province of Ontario has a number of statutes, guidelines, and policy statements concerning environmental planning and protection which are mandated for projects such as the Deep Lake Water Cooling System Project. The primary approval requirement is Ontario's Environmental Assessment Act. This particular statute has been enforced for approximately 15 years. Its primary purpose is to provide a planning and decision-making model for undertakings (projects) that will involve potential environmental impact. In addition, there are a number of statutes which are concerned with environmental and resource protection measures and, finally, there are a variety of land use planning requirements that proponents must fulfil. The purpose of this section is to provide a fairly comprehensive overview of the approval's requirements for a project such as the Deep Lake Water Cooling System Project and, for those not familiar with the major environmental requirements of the Province, to provide a summary of the requirements of the legislation.

2.2 The Ontario Environmental Assessment Act

The purpose of the Environmental Assessment Act is to provide proponents with a rational planning model for evaluating potential environmental effects and for making decisions on the environmental appropriateness of their projects. In the language of environmental assessment in Ontario proponents are the initiators of undertakings governed by the Act. An undertaking can be any enterprise or activity including plans or programs, engineering or design projects. The Act applies to any undertakings on behalf of the Government of Ontario or public bodies defined by regulation including, since the early 1980s, municipalities. Crown agencies or public agencies are also governed by this statute. Private sector undertakings, or any other category of project may be designated by the Minister of the Environment (MOE).

One of the most important characteristics of the Environment Assessment Act is the way in which it defines "environment". The definition of the environment in clause 1(c) is known as the "broad definition of the environment" because it does not simply include reference to the natural environment - air, land or water, plant and animal life, including man. The broad definition also deals with social, economic, and cultural conditions including any device or thing made by man and; solids, liquids, gases, odours, heat, sound, vibration or radiation resulting from activities of man and, any of the interactions among these various categories. The definition of the environment used by the Act is therefore much broader than most statutes and incorporates both the natural and physical features into the human elements of the environment.

In addition to the broad definition of the environment, the Act contains in sub-section 5(3), a comprehensive model for decision-making. This subsection differentiates the Environmental Assessment Act from many other environmental planning and protection statutes. It requires that a proponent submit for approval an Environmental Assessment which documents:

- a description of the purpose of the undertaking;
- a description and statement of rationale for the undertaking, alternatives to the undertaking and alternative methods of carrying out the preferred undertaking;
- a description of the environment that might be affected or reasonably expected to be effected;
- the effects, and the actions necessary to mitigate or remedy the potential effects upon the environment; and
- a summary evaluation of advantages and disadvantages of the preferred course of action (the undertaking) and alternatives to the undertaking.

One can see that the framers of this legislation were interested in understanding in a systematic way the types of decisions made to carry a project forward from the earliest stages of project initiation to implementation. One of the more salient features of this decision-making model is the requirement that the initiator of projects consider the "do- nothing" alternative. The "do-nothing" alternative involves an examination of how the environment would be affected if the project were not implemented. The court's have interpreted this requirement as providing a base line of environmental information to assist in contrasting or comparing the preferred course of action (the preferred alternative) to existing conditions. In this way, regulators and others evaluating the environmental assessment document can make judgements on the net environmental costs and benefits of any project.

At all stages of decision-making, including the appropriateness of the goals and objectives of a given project, the strategic alternatives that could be implemented to achieve the stated goals and objectives, and the various locational, design, construction and operational alternatives to implementing a given strategic alternative to the environment must be considered. The net environmental effects of each alternative are analyzed in terms of potential environmental effects. Based on this information, the proponent must carry out an evaluation of the advantages and disadvantages of each of the alternatives and select the one that is the most environmentally appropriate.

The proponent has the responsibility of developing the range of strategic alternatives and options, and also of selecting the level of detail of environmental analysis by which these options are evaluated. As the environmental assessment is a public document, and considering that the issue of environmental approval may be manifest in a formal hearing before a panel of the Environmental Assessment Board, the decisions on the types of alternatives and the ways in which they are evaluated are usually closely scrutinized. The proponent may have the freedom to select alternatives, but he or she must also defend the selection and the way in which each is assessed.

Another important feature of the way in which the Environmental Assessment Act is implemented deals with public participation. The Environmental Assessment is a public document, filed with the Ministry of the Environment. In addition to the Environmental assessment, all of the subsidiary studies, reports and material used in the Environmental Assessment process are available for public review, unless under very special circumstances, the information is restricted. The general public, as well as non-government agencies and groups are encouraged to take active part in the environmental assessment. This may take the form of public liaison committees, meetings, workshops, and other formal mechanisms. The way in which the public is involved will be carefully considered by review agencies. It is entirely up to the proponent to decide on the organization of public participation in his or her environmental assessment. It is fair to say that any project without a realistic and constructive public participation program runs the serious risk of being considered deficient.

The Environmental Assessment Act requires fundamental decisions to be made. No project can be implemented without the Minister's (MOE) approval. Once the Environmental Assessment is completed and the process is documented and submitted, procedurally, the Environmental Assessment documentation is formally submitted to the Minister of the Environment. His or her staff, coordinated by the Environmental Assessment Branch, along with all formally recognized parties and the public in general, have an opportunity to review the Environmental Assessment. In reviewing the Environmental Assessment, Ministry Staff are concerned with providing advice to the Minister regarding two basic questions:

- whether the Environmental Assessment documentation meets the requirements of the Act and is acceptable; and,
- whether the undertaking documented by the Environmental Assessment is acceptable.

It may well be that the Minister is unable to make a decision on the appropriateness or acceptability of a proponent's undertaking because the documentation is incomplete or deficient.

In this case, the Minister has a number of options including amending the Environmental Assessment, requiring more studies, requiring a hearing to proceed or not accepting the Environmental Assessment. Discussion between the proponent and the Ministry staff or other parties usually precedes recommendations on the acceptability of an Environmental Assessment. It often occurs that amendments are made or revisions are carried out by the proponent in the face of documented criticism. Once the Environmental Assessment is accepted by the Minister, notice of the acceptance, or acceptance and amendment of the Environmental Assessment, is made to the public and to any parties that the Minister may designate.

The next decision the Minister must make is on the acceptability of the undertaking that the Environmental Assessment documents. The Minister may:

- give approval to proceed with the undertaking;
- give approval to proceed subject to terms and conditions the Minister considers necessary;
- refuse to give approval to proceed with the undertaking;
- require that the Environmental Assessment Board or a Joint Board hold a Hearing.

Not all Environmental Assessments result in a Hearing before the Environmental Assessment Board or the Joint Board. If the Hearing does proceed, it is usually before a panel of the Environmental Assessment Board, or before a Joint Board consisting of members of an Environmental Assessment Board and members of other administrative tribunals (typically the Ontario Municipal Board). The provision of a Joint Board was mandated by the Consolidated Hearings Act which recognized that undertakings often involve approvals under a variety of statutes. The Consolidated Hearings Act allows all approvals to be granted under one Hearing. The tribunal hears evidence, administers proceedings, makes decisions on procedure and ultimately writes the decision which recommends approval, approval with amendment, or non-approval of the undertaking before it. The administrative tribunals are invariably open to the public and to a variety of interests and organizations. The public at large is given ample opportunity to make submissions to the Board and to address the Hearing. In most cases, the proponent and at least the major parties to the proceeding are represented by legal counsel.

Upon the completion of the Hearing, the Board writes a Decision and submits it to the Minister of the Environment. The Minister, with the approval of the Lieutenant Governor in Council, can accept the Board's Decision which may be approval, or approval with amendments, or non-approval. The Minister may vary, in whole or any part, the Board's Decision, and may substitute his or her own decision.

Finally, the Minister has the option of requiring a Board to hold a new Hearing on the matter, or any part of the matter, concerning the Decision if he or she is not satisfied with the Decision. The rights of appeal regarding the decision of the Minister are essentially restricted to the Petition for a Judicial Review, or an Appeal to Cabinet.

The primary considerations in judging the adequacy of an Environmental Assessment and the understanding that it documents are founded in the "broad definition of the environment" together with the core requirements of subsection 5(3) in the context of the purpose of the Act which is specified in section 2 - provision for the "protection, conservation and wise management in Ontario of the environment". Those approving the Environmental Assessment will want to look at the way that the problem was defined, ensuring a broad range of planning options is considered in meeting the goals and objectives. They will also want to consider the breadth and relevance of the range of planning alternatives considered as well as options implicit in affecting alternatives. The Environmental Assessment should provide the appropriate base line information and detail on the environment to allow for a reasonable assessment of impacts. The analysis should be traceable and replicable for those reviewing the document and attempting to understand the hierarchy of decisions made to arrive at the preferred alternative. Finally, there should be evidence that a constructive public and open planning process was used to determine whether or not the preferred alternative met the requirements of the Act.

2.3 Other Provincial Approvals

The Province of Ontario has a number of laws and regulations pertaining to the environmental protection and management of resources that would come into play if the deep water cooling concept becomes reality. Under the mandate of the Ministry of Natural Resources, four pieces of legislation have particular relevance to projects such as the Deep Lake Water Cooling System Project. The Public Lands Act and the Lakes and Rivers Improvement Act are both statutes dealing with activities relating to Crown Land and surface waters. In addition, the Ministry of Natural Resources has a role in enforcing the Federal Fisheries Act. This Act deals with fisheries and aquatic resources and surface water environments. Similarly, the Ministry of the Environment has the mandate to protect the surface waters and ground water quality in the Province. The Ontario Water Resources Act deals directly with projects effecting water resources.

There has been an attempt by these and other agencies, including the Federal Government, to coordinate their interest and approvals regarding projects such as the Deep Lake Water Cooling Project. This generally means the permitting or approval requirements for one agency will be accepted by another in terms of their own statutory requirements and mandate.

Under the Ontario Water Resources Act, Sections 20 and 24 require permits to take water and control the discharge of water into surface water features. Flowing from this statute are a number of policy statement guidelines and regulations which specify more precisely the requirements for working in surface waters. An example of this would be policy guidelines that set limits on the temperature differences that are allowed between ambient and discharged waters. Under the Public Lands Act the Ministry requires an application for a work permit and an application to do work on shore lines. These requirements are administered under clauses involving the granting of easements for individuals to work on public lands. The permitting process under both the Ontario Water Resources Act and the Public Lands and Lakes and Rivers Improvements Act require a common base of information on predicted impacts and conditions of operation that must be met.

At a local level, under the Planning Act, provisions for land use changes and activities requiring official plan status, zoning or site development provisions are generally supervised by the local municipality. There may be special provisions required under environmental planning policies. However in most cases, the Planning Act requirements will be met through the normal development process at a local or regional level. Such matters as easements and access control, discharge of waters into storm or sanitary sewers, land development and site control provisions are generally approved and monitored through local governments.

The Metropolitan Toronto and Region Conservation Authority (MTRCA) is a local government agency operating under referred powers from the province (Ministry of Natural Resources). They have jurisdiction over activities in flood plains and involving water flow modification. They are the agency responsible for provincial crown waterfront lands and landfilled areas in the Toronto area. They have the authority to regulate flood plain works and are one of the key agencies reviewing proposals for projects along shore lines of lakes and rivers. They work in close concert with provincial ministries to regulate construction, spoil disposal and shoreline modifications along the land front.

2.4 Federal Government Requirements

The Federal Government maintains a mandate over navigable waters, international boundary waters, and has environmental approvals policies for Federal projects. The Deep Lake Water Cooling Project will involve federal review for the activities potentially affecting fisheries, water quality, marine transport and Federal lands.

The Fisheries Act concerns potential changes to fish habitat and the effects of deleterious substances that may enter surface waters. This statute is administered at a local level by the Ministry of Natural Resources.

The Navigatable Waters Protection Act concerns disruption to marine traffic and navigation and is administered by Transport Canada. Along with Environment Canada and key provincial ministries, Transport Canada and the Canadian Coast Guard will be given a review role on any proposals involving work in Lake Ontario.

In general, the requirements of Provincial and Federal agencies are combined and coordinated with regard to approval permits and their appended conditions of approval.

Finally, the major regulatory agencies include the Crombie Commission on the Toronto Waterfront. At this time, their role in the approval hierarchy for this project is being resolved, however, as a commission with oversight planning authority for harbour lands they will be on a regulatory review circulation schedule for development of project approvals.

2.5 The Environmental Assessment Framework for the Deep Lake Water Cooling Concept

At this stage of planning, the Deep Lake Water Cooling Concept is being treated as a potential project that would be subject to an Environmental Assessment. Although the status may change, the project is appropriately considered as a public sector initiative with capital costs and scale typical of environmental assessments completed by provincial and municipal governments and agencies. Its benefits are directed at a mix of public and private sector facilities. Potentially it has strong support from the Ministry of Energy and the City of Toronto.

As an environmental assessment the project must identify and evaluate alternatives and establish a need and rationale through an evaluation process which takes into account the potential impacts, mitigation and net effects of the project on the environment.

The following is a preliminary outline of the framework for an environmental assessment for the project:

2.5.1 Need and Rationale

The need for the project is defined in terms of overall goals and objectives and the benefit to the environment.

Primary Objective:

- To provide a safe, environmentally sound source of cooling for a wide range of private and public buildings/facilities in the City of Toronto central core area;

Subsidiary Objectives:

- To enhance the local and regional quality of the environment, specifically the air environment;
- To provide greater energy efficiency systems in Toronto and reduce electrical energy use for space cooling, particularly peak electrical demand.

The rationale, as required by the Act, is the summary of decisions and conclusions that were made throughout the planning and evaluation process used to arrive at the preferred alternative and its net environmental effects. The rationale is usually written at the end of the planning process.

Lastly, the study area is defined with development of the rationale.

2.5.2 Alternatives to the Undertaking

(i) The "do-nothing" alternative considers the predicted state of the environment if a Deep Lake Water Cooling System is not implemented. One can presume that electrically driven chillers will continue to provide (on an individual building by building basis), the space cooling needed for development. Potential impacts would include:

- costs
- reliability
- energy deficiencies
- energy consumption trends and capacities
- CFCs
- indirect effects from electric power production
- nuisance effects
- meso-climate effects
- etc.

(ii) New Technology for Chillers. This alternative would canvass the existing initiatives in chiller technology to evaluate the potential for meeting the objectives without relying on the DLWCS. Environmental benefits and impacts would be evaluated along the same lines as the factors in (i) above. New technologies may offer cost and comparable efficiency benefits.

(iii) Ban on Air Conditioning. One important alternative may be a regulatory ban on the use of any space cooling or air conditioning. A discussion of the benefits in cost and environmental impact would have to be contrasted with quality of work place issues, health and productivity concerns. This alternative may act as a useful introduction to alternative (iv) below.

(iv) Increased thermal ambient energy conservation. This alternative deals with the options for reducing solar and atmospheric short and long wave radiation gain in structures. A variety of measures related to building operations, insulation, orientation and design may preclude the use of active cooling.

(v) Deep Lake Water Cooling System. The benefits of this alternative - at this stage the preferred option, will be detailed and contrasted with other options. The alternatives, particularly the preferred alternative, must be evaluated in some detail in the context of the stated problem to be solved/goal to be met. Environmental benefits must be clearly elucidated.

2.5.3 Alternative Methods of Carrying Out the Undertaking

Once the alternatives (section 2.5.2) have been identified and evaluated; and a preferred alternative is selected, alternative methods of carrying out the preferred alternative must be identified.

As the preferred alternative from section 2.5.2 above is assumed to be the Deep Lake Water Cooling System, the following initial list applies to this concept:

(i) Alternative service areas can be defined along with the range of alternative capacities and flow rates required.

(ii) Alternative intake options can be identified with regard to:

- depth and distance from shore
- routes
- type of facility (tunnel or trench)
- number of return outfalls
- subsidiary options (i.e. Don River augmentation)
- other

(iii) Technology options, including:

- intake structures
- pumps and circulation technology
- materials
- circulation and service configuration
- other

(iv) Construction Options

- micro tunnelling
- integration with existing service facilities
- spoil disposal options
- other

2.5.4 Documentation

The various options of designing and implementing the Deep Lake Water Cooling System must be evaluated, considering the environmental effects, mitigation and net costs and benefits to the environment. These aspects are evaluated for the preferred option in comparison with the alternatives. The following documentation subject headings provide some insight regarding the scope of this effort:

(i) Description of the Preferred Alternative

- the undertaking

(ii) Description of the Environment

- the aspects of the environment that will or could be affected by the undertaking, and what can reasonably be expected to be affected by the undertaking; e.g.
    - the lake, lake biota
    - the lake shore
    - the City downtown core
    - the regional and local airshed
    - the Don River

- the Toronto Harbour
- residents, employees
- etc.

(iii) Opportunities for Mitigation

- design
- construction
- operations

(iv) Description of Net Environmental Effects and Opportunities

- negative impacts
- benefits

(v) Additional Approvals Requirements and Monitoring Needs; Conditions of Approval

- construction, rehabilitation
- operation

(vi) The Rationale for the Undertaking

- a precis of this section would form an introduction to the EA application documentation

(vii) Appendices

- Support/Special Studies
- Public Participation Program
- Design specs
- References
- Contacts and Agency/Public Comments

2.5.5 The Next Stage

The first task of the planning and design team examining the Deep Lake Water Cooling System concept will be to review the project goals, objectives and potential characteristics to decide on the approvals requirements and environmental assessment status. Pre-submission consultation with MOE and review agency staff will expedite this stage and help establish a terms of reference and study design that is appropriate for ultimate submission of an environmental assessment.

The outline of approvals and environmental assessment needs and framework of the Environmental Assessment document described above should provide a context for understanding the impact of the approvals step in the process of implementing "Deep Water Cooling".

3.0 COOLING WATER DISCHARGE STUDY

3.1 General

The main purpose of this section is to discuss the impact of alternate discharge schemes that could be implemented with the proposed Lake Water Cooling (LWC) concept on the Toronto Waterways.

Lake Water Cooling is a concept for cooling buildings in downtown Toronto using cold water drawn from a depth of 80 m in Lake Ontario. The water is conveyed to the pump house through an intake tunnel, pumped into north-south discharge tunnels from the Lake Shore to Bloor Street and delivered to the buildings along the way through east-west connecting tunnels and piping systems. The return water is conveyed back to the Lake through similar tunnel and piping systems. The outfall is proposed to be a 4.5 m high by 3.0 m wide box culvert that discharges into the Inner Harbour at the York Street Slip. The top of the culvert would be 2.3 m below the harbour water level.

The extent of the deep water cooling concept service area is assumed to be bounded by the Lakeshore Blvd., Bloor Street, Jarvis Street and Spadina Avenue. Based on EIL position paper, cooling water will be required all year round, with the peak flow ranging from 4.9 m^3/s during December to February, up to 37.9 m^3/s being required during June to August. The respective average daily flow is projected by EIL as varying from 1.0 m^3/s in winter to 11.7 m^3/s during the summer.

This section of the report addresses the potential environmental impact of the return water on the receiving water bodies, and considered the following:

1) With the return water temperature at 13°C, what degree of temperature increase/reduction can be expected during winter/summer, and to what extent.

2) The return "uncontaminated" water will have flushing effects on the "contaminated" waterways and will reduce pollutant concentrations. For this study, Fecal Coliform was considered as being representative of various contaminant parameters, therefore the impact of return water on Fecal Coliform concentration in the Toronto Harbour and Don River was studied.

3) Potential impact of return water discharge on other environmental aspects are discussed, including the following:

   a) Differential in the oxygen content between the return water and receiving waters
   b) Stirring up or re-entrainment of deposited sediments
   c) Impact on the currents in the Toronto Harbour, Eastern and Western Gaps, and the Lake
   d) Flooding along shoreline and along waterways
   e) Impact on the formation of ice cover during winter

3.2 Alternate Discharge Schemes

To study the impact of discharging the deep water cooling system return uncontaminated water to the Inner Harbour, or other waterways in Toronto, the following alternate discharge schemes were developed and studied:

1) The total return flow discharges into the Inner Harbour via a single box culvert at the York Street Slip.

2) The total return flow discharged into the Inner Harbour via two discharge locations, one at the Spadina Avenue slip and the other at the Jarvis Street slip. This option provides more effective flushing of the Inner Harbour through the Western and Eastern Gaps.

3) Discharge a maximum of 10 m^3/s of the total return flow to the Don River near Bloor Street, and the balance to the Inner Harbour, either at one location as in Alternative 1, or at the two locations as in Alternative 2.

Under Alternatives 1 and 2, the return water discharges to the Harbour as proposed by EIL via box culverts, discharging at the wall of the slip. Alternative 3 considers extending a tunnel along Bloor Street, east of Jarvis Street, to the Rosedale Valley Road. At this point, the water will rise in a shaft where it will be conveyed a distance of about 1500 m to the Don River along the Rosedale Valley Road, either via below grade sewer or via open channel flow. The open channel concept would be grassed lined, approximately 8.8 m top width and 1.0 m deep. If this alternative is found feasible and acceptable to the public, and authorities having jurisdiction, its natural appearance could provide positive aesthetic value to the Rosedale Valley. If the open channel option is not considered to be beneficial to the area, a 2.0 m diameter buried conduit could be used.

Regardless of the conveyance system selected, energy dissipation devices would have to be provided in the tunnel east of Jarvis Street and/or in the shaft.

3.3 Method of Evaluation

To evaluate the impact of the return water quality and temperature on the Inner Harbour, the Rand two dimensional water quality model was used. This model is based on the City of Toronto Combined Sewer Overflow model grid. This model has a grid size of 60 m and ample resolution for the major shoreline features. All inflows to the Harbour are modelled, including sewer discharges, Keating Channel, and the proposed return deep lake water. The Harbour is connected to the Lake by the Western and the Eastern Gaps.

The model is driven by a constant westerly current out of the Western Channel with a speed of 10 cm/s. The wind influence was based on wind data collected at Toronto Island Airport. The City of Toronto QQS (Quantity-Quality Simulation) model was used to provide Fecal Coliform pollutographs for a wet weather event. The April 1980 event was selected as it represents a storm event which may occur 2 to 3 times per year on the average.

Different time steps were initially used to run the Rand model. A 1 minute time step was ultimately selected, as the longer time steps resulted in model instabilities.

To evaluate the impacts of the return water on the Inner Harbour, extreme conditions were investigated. These conditions included wet and dry weather events and summer and winter periods. The various scenarios investigated for the three alternate discharge schemes identified in section 3.2 are presented below.

1) Wet weather flow event in the summer to assess effects on temperature and Fecal Coliform.

2) Dry weather flow event in the summer to assess effects on temperature and Fecal Coliform.

3) Dry weather flow event in the winter only for alternative Schemes 1 and 2 for temperature only. Scheme 3 was not modelled since it is assumed no flow would be discharged to the Don River during the winter.

4) Wet weather flow event in summer under present condition (no return water) for Fecal Coliform. This establishes the 'do-nothing' baseline case.

The result of the computer simulations for each of the above scenarios are discussed in Section 3.4.

3.4 Impact on Inner Harbour

3.4.1 General

Extensive computer plots were generated for the various scenarios identified in Section 3.3. This work was performed by Gore and Storrie Limited under the direction of MacViro. This report presents a summary of the anticipated temperature and Fecal Coliform impacts along with representative computer plots.

3.4.2 Temperature Impact

3.4.2.1 Summer Wet Weather Event

For demonstration purposes, two summer wet weather temperature deficit contour plots are presented. Figure 7A shows the temperature deficit as a result of a single discharge at the York Street Slip and Figure 16B resulting from 10 m^3/s diverted to the Don River and two discharge points (Jarvis Street and Spadina Avenue) to the Inner Harbour. The contours represent the temperature deficit in the harbour from the initial temperature at 24°C. Figure 7A indicates that the temperature deficit is generally 1-3°C with a localized pocket of 4°C near the point of discharge (York Street Slip). The effect of two discharges and 10 m^3/s to the Don River is over a larger area of the Inner Harbour but the temperature deficit of 1-2°C is less than the Figure 7A scenario. Temperature deficits of 3-4°C occur near the two points of discharge.

3.4.2.2 Summer Dry Weather Event

For the summer dry weather event, temperature deficit contour plots are presented for a total discharge at York Street Slip (Figure 7I) and separate discharge at Jarvis Street and Spadina Avenue and 10 m^3/s at the Don River (Figure 8I).

In the first scenario, the mean value of the steady-state deficit is about 2.15°C with most of the deficit occurring west of the discharge point and at the point of discharge. In the second scenario, the mean deficit has been reduced to about 1.75°C. For the latter case the zone of 1°C temperature deficit has reduced and only occupies the north shoreline of the Harbour. Localized temperature deficits of up to 5°C occur at the two points of discharge.

3.4.2.3 Winter Dry Weather Event

The two discharge scenarios identified in Section 3.4.2.2 were also modelled for the winter dry weather event. The impact of the single discharge at York Street slip is shown in Figure 5 and that for the two discharges in Figure 6. Discharges to the Don River during the winter period are not proposed.

Figure 5 shows a reduced area of temperature excess. A small zone with a 1°C temperature excess is predicted about 250 m offshore and 750 m alongshore. Since the discharge is buoyant, there will be a surface plume which will probably be larger than the zone predicted by this model.

Figure 6 shows that the two discharge locations reduce the size of the temperature excess zones at each locations. The zones extend about 60 m offshore and 250 m alongshore at each location. Again a surface plume will probably exist at each site.

3.4.3 Water Quality Impacts

3.4.3.1 Summer Wet Weather Event

A summer wet weather condition was run under existing conditions (no return water to the Inner Harbour or Don River) to establish the base condition for Fecal Coliform. In the computer simulation, the background Fecal Coliform densities in the Harbour were set to 10 FC/100 mL, the Don river 500 FC/100 mL and the LWC discharge 1 FC/100 mL.

The Fecal Coliform density contours for the existing condition are shown in Figure 15B. As shown in this figure the 500 FC/100 mL and 1,000 FC/100 mL contours are fairly uniformly distributed throughout the Inner Harbour but the 2,000 FC/100 mL is concentrated along the shoreline where a number of outfalls exist.

The FC density contours for a single return water discharge to the York Street Slip are shown in Figure 9B, two separate discharges are shown in Figure 10B and 10 m^3/s to the Don River with two discharges to the harbour are shown in Figure 17B. Figure 9B indicates high levels of Fecal Coliform with at least 2,000 FC/100 mL observed. At a reference point about 120 m south of the York Street Slip discharge location, the York Street Slip scenario has mean FC values of 100 FC/100 mL lower than the present condition. The mean value at the reference point is observed to be about 200 FC/100 mL.

Figure 10B demonstrates that the two discharges reduce the over impact of the Don River plume and the stormwater plumes by supplying dilution water at two locations. However, there is no effect on the Turning Basin FC densities. The mean level at the reference point is observed to be about 125 FC/100 mL.

In Figure 17B, the Don River FC density was set to 500 FC/100 mL during the period when there was no return water discharge and was reduced to 315 FC/100 mL by mass balance when there was discharge. The return water FC density remained at 1 FC/100 mL and the harbour at 10 FC/100 mL. With the above assumptions, the mean concentration level at the reference point was reduced to about 115 FC/100 mL.

3.4.3.2 Summer Dry Weather Event

Summer dry weather Fecal Coliform density plots for the single York Street Slip discharge, the two discharge scenario and the 10 m^3/s diversion to the Don River scenario are presented in Figures 12B, 13B and 14B, respectively.

Figure 12B shows the single discharge at the York Street slip impact on the FC densities in the harbour. Its major impact is from the Don River plume. The steady-state FC density at the reference point 120 m south of the York Street slip is about 25 FC/100 mL, which is the well mixed portion of the Don River plume.

Figure 13B also shows only the plume from the Don River. The steady-state FC density at the reference point is about 27 FC/100 mL which is the well mixed portion of the Don River plume. The two discharge locations option has increased FC densities at the reference point since the dilution effect of the LWC discharge is spread over a larger area.

For the scenario shown in Figure 14B (10 m^3/s to the Don River and two discharge location to the harbour), the background conditions remain the same in the harbour and LWC discharge. The Don River has a background FC density of 500 FC/100 mL and a discharge rate of 3 m^3/s when not receiving LWC. When LWC is discharged, the rate in the Don River is 13 m^3/s and the mass balance FC density is 126 FC/mL.

Figure 14B indicates that the LWC discharge to the Don River reduces the impact of FC on the Harbour. The steady-state FC density is about 24 FC/100 mL, at the above noted reference point.

3.4.3.3 Winter Dry Weather Event

Fecal Coliform densities during the winter are not of concern therefore this event was not modelled.

3.5 Impact on the Don River

3.5.1 Present Water Quality in the Don River

The in-stream water quality throughout most of the Don River is considerably degraded due to various sources of pollution. Water quality problems tend to be worst in the lower reaches of the Don River, due to the higher level of urbanization, discharge of combined sewer overflows and the presence of the North Toronto Sewage Treatment Plant.

Water quality data obtained in the TAWMS (Toronto Area Watershed Management Strategy) studies indicate that the river is often turbid and eutrophic. Concentrations of pollutants tend to be lowest for dry weather conditions and increase by a factor of 1 to 30 during storm events. As a result, the Provincial Water Quality Objectives (PWQOs) have been exceeded for a wide range of parameters, including heavy metals, nutrients, bacteria and some organic compounds. Comparison of in-stream water quality concentration for Fecal Coliform shows that it exceeds the Provincial target value of 100 counts/100 mL, 75-96 percent of the time.

Despite the fairly high pollutant concentrations, the river has plentiful oxygen resources with few observations below 6 mg/L. Summer water temperatures are fairly high, ranging from about

10°C in June to about 25°C in August.

In the past, various abatement works and monitoring programs have been carried out on the Don River. Abatement efforts include the identification and removal of illegal sewer connections, spill controls and the installation of storm water management facilities. Recently, remedial and mitigative measures have been proposed, including:

- installation of combined sewer overflow controls
- incorporation of storm water quality ponds
- prevention of storm water contamination at the source
- sewage treatment plant upgrade or decommissioning

3.5.2 Impacts of Lake Water Cooling Discharges

3.5.2.1 General

According to the Metro Toronto Remedial Action Plan (RAP) Discussion Paper (April 1990), the cost for cleaning up the Don River could range between $30 and $60 million per year if the highest level of improvement is desired. This effort would be required over a 10 to 20 year period, exceeding a total capital expenditure of about $1 billion. Given the level of the proposed expenditure and time frame to achieve the improvement, it was decided to assess the benefits and adverse impacts that might be obtained by discharging about 10 m^3/s of the return water into the Don River from 6 a.m. - 6 p.m. during the summer period. This time frame was selected considering the cooling load, and therefore deep water flow rates are reduced to minimal levels during the night.

3.5.2.2 Temperature

As noted previously, the return water proposed to be discharged into the Don River will have a temperature of 13°C. Discharging the water either via an open channel or buried conduit is not likely to affect the temperature significantly, since the travel time to the Don River is estimated to be between 10-15 minutes. A slight increase in temperature may occur for the open channel alternative, or a slight decrease for the buried conduit option.

Depending on the summer month, the return water may either increase or decrease the Don River water temperature. It is expected that during June the temperature at the discharge location may increase by 2-3°C while during July/August, the temperature may decrease by 5-8°C. This impact will decrease along the River and, using a mass balance equation, the deficit temperature at the Keating Channel during summer was calculated to be 2.2°C below natural river temperature. The possible impact of the change in temperature on fish and other aquatic life should be investigated in future studies.

3.5.2.3 Water Quality

For the purpose of this study, Fecal Coliform (FC) was selected as an indicator of water contamination in the Don River. For the computer simulation, the Don River was assumed to have a background FC density of 500 FC/100 mL. The mean monthly flow along the lower Don River was estimated at 3 m^3/s, based on historical flow data. With the discharge of 10 m^3/s from the Lake Water Cooling concept return water, the flow in the river is assumed to increase three-fold, thereby reducing the FC density to about 126 FC/100 mL.

3.6 Other Potential Impacts

3.6.1 Inner Harbour

3.6.1.1 Oxygen Levels

The oxygen content of the return water is expected to be lower due to the elevated pressure and temperature within the supply and return system. The provision of air diffusers prior to the discharge to the Inner Harbour will ensure that the proper dissolved oxygen levels are achieved in order to minimize impact on fish and aquatic plant life.

3.6.1.2 Stirring of Deposited Sediments

According to hydrographic mapping of the Toronto Harbour, the mean depth of water at the York Street, Jarvis Street and Spadina Avenue slips is generally greater than 6 m. Since the return water is proposed to be discharged about 2 m, below the lake level, it is unlikely that the discharge jet will have significant impact on the scouring and entrainment of bottom sediments. Some disturbance may occur but it is expected to be localized to the discharge points.

3.6.1.3 Impact on Lake Current

The return water is not expected to cause any impacts on currents in the lake.

3.6.1.4 Flooding

The volume of return water discharged to the lake is relatively small, consequently, no significant impact on shoreline flooding is anticipated.

3.6.1.5 Ice Cover

Temperature excess is localized to the points of discharge in the Inner Harbour. The impact on the formation of ice cover is localized to either the York Street Slip or the discharge points at Jarvis Street and Spadina Avenue. The ice free locations at these points could promote the year round operation of docking facilities.

3.6.2 Don River

3.6.2.1 Oxygen Levels

At the exit from the tunnel in the Danforth Road/Sherbourne Street area, the return water will have an oxygen deficit due to the elevated system temperature and pressure. Before it can be discharged into the Don River, the water needs to be aerated to increase its dissolved oxygen content. If the water is conveyed to the Don River via an open channel along Rosedale Valley Road, the return water will be aerated sufficiently naturally. If the water is conveyed via a buried conduit, other design features such as centrifugal blower supplied air diffusers or grated man-holes will likely have to be incorporated to positively aerate the water.

The return water will be relatively clean and will not introduce any organic load into the Don River that will result in reduced dissolved oxygen. Hence, the additional supply of water will produce higher levels of dissolved oxygen than presently exist in the Don River, improving the environment for aquatic life forms.

3.6.2.2 Flooding

Flooding on the Don River has historically occurred at any time of the year as a result of rainfall, snow melt or a combination of the two events. Some flooding of the lower Don River occurs when flows are in excess of 150 m^3/s. During these high flow periods, it will be necessary to shut-off the supply of deep water cooling system return water to the Don River in order not to aggravate the flooding situation.

The effective control of discharges to the Don River during flooding conditions will require a monitoring system to measure and respond to the Don River flood levels. A control gate at the outlet of the tunnel to re-direct the return water to the harbour will also be required.

3.6.2.3 Erosion and Sedimentation

Flows for the 1:1 and 1:2 year return periods are not available for the Don River to compute channel velocities. However, the 1:5 year flow (280 m^3/s) for the lower Don River produces channel velocities in the range of 1.70 to 2.0 m/s. Consequently the addition of 10 m^3/s to the Don River during high flows is not going to significantly increase channel velocities. Similarly, under low flow conditions, the addition of 10 m^3/s to the Don River will not increase channel velocities substantially due to the size of the channel, the relatively flat slope of the lower Don River and the backwater effects from the Keating Channel. Consequently existing erosion and sedimentation problems will not be made worse by the additional discharge from the Lake Water Cooling system.

Local erosion protection works will have to be provided at the outlet to the Don River (Bayview Avenue and Rosedale Valley Road area) to stabilize the bank and the channel in the area.

3.6.2.4 River Flushing

The additional supply of water will generally improve the overall water quality of the Don River from the point of discharge during the summer period. However, due to the obstruction created by the sediments deposited at the Keating Channel, it will not be possible to flush all the pollutants out of the Don River system, even with the additional source of water.

3.6.2.5 Ice Cover

Return water will not be discharged to the Don River during the winter months, hence the impact on ice cover formation on the Don River is not a consideration.

3.7 Summary of Conclusions

3.7.1 Conclusions

In the study undertaken, three alternative discharge schemes were investigated under wet and dry weather events and summer and winter periods. The main purpose of the investigation was to assess the impacts of the three schemes under various scenarios on temperature and water quality aspects both in the Inner Harbour and along the Lower Don River.

The results of the study should be considered preliminary since several assumptions in the computer modelling had to be made due to lack of adequate data. However, preliminary indications are that the discharge scheme that has the least impact on the harbour temperature is the one with two discharge points (Jarvis Street and Spadina Avenue) and 10 m^3/s diverted to the Don River. The other scenarios have larger zones of temperature deficit in the summer and temperature excess in the winter. This scheme has also the lowest Fecal Coliform densities in the harbour and the Don River.

The scheme has distinct benefits in improving the existing water quality (FC) in the harbour and along the Lower Don River by providing the dilution to reduce the concentration of pollutants. However, impact of temperature changes on the fish and other aquatic life both in the Don River and harbour needs to be investigated further.

3.7.2 Future Studies

The studies presented in this report are based on certain assumptions including:

- current speed of 10 cm/sec at the western channel
- constant flows and concentrations from the Don River to the Inner Harbour
- only the extreme winter and summer conditions were examined and only one storm event was modelled

In addition, the studies considered well-mixed substances but the spreading of buoyant/non-buoyant discharges especially with heat transfer as a major factor was not modelled.

During 1991-1992, the MOE will be collecting water current and quality data at each of the gaps in the harbour. The use of these data in future studies should provide much more reliable predictions than the present simulations. Also, the current model can simulate the advection of a substance in the upper/lower layer of the water column, if the depth of the layer is known. Some estimate of this layer could be made in order to more accurately estimate the impact of the discharge in summer and winter. Future studies should also consider continuous simulation from April to October of an average wet year (say, 1980). This simulation will provide the following:

1. The impact of the different alternate discharge schemes on the Harbour water quality for average wet year conditions. Comparison between the impact of the different schemes

will be based on different storm and current conditions.

2. The impact on the Harbour water temperature for different periods of the year, not only on the extreme conditions. Of particular interest would be the prediction of the change in temperature during fish spawning periods.

Future studies should also consider other discharge schemes including alternate discharge locations and different discharge rates to the Don River. Associated changes in temperature and oxygen levels should also be investigated in view of impacts on fish and other aquatic life.

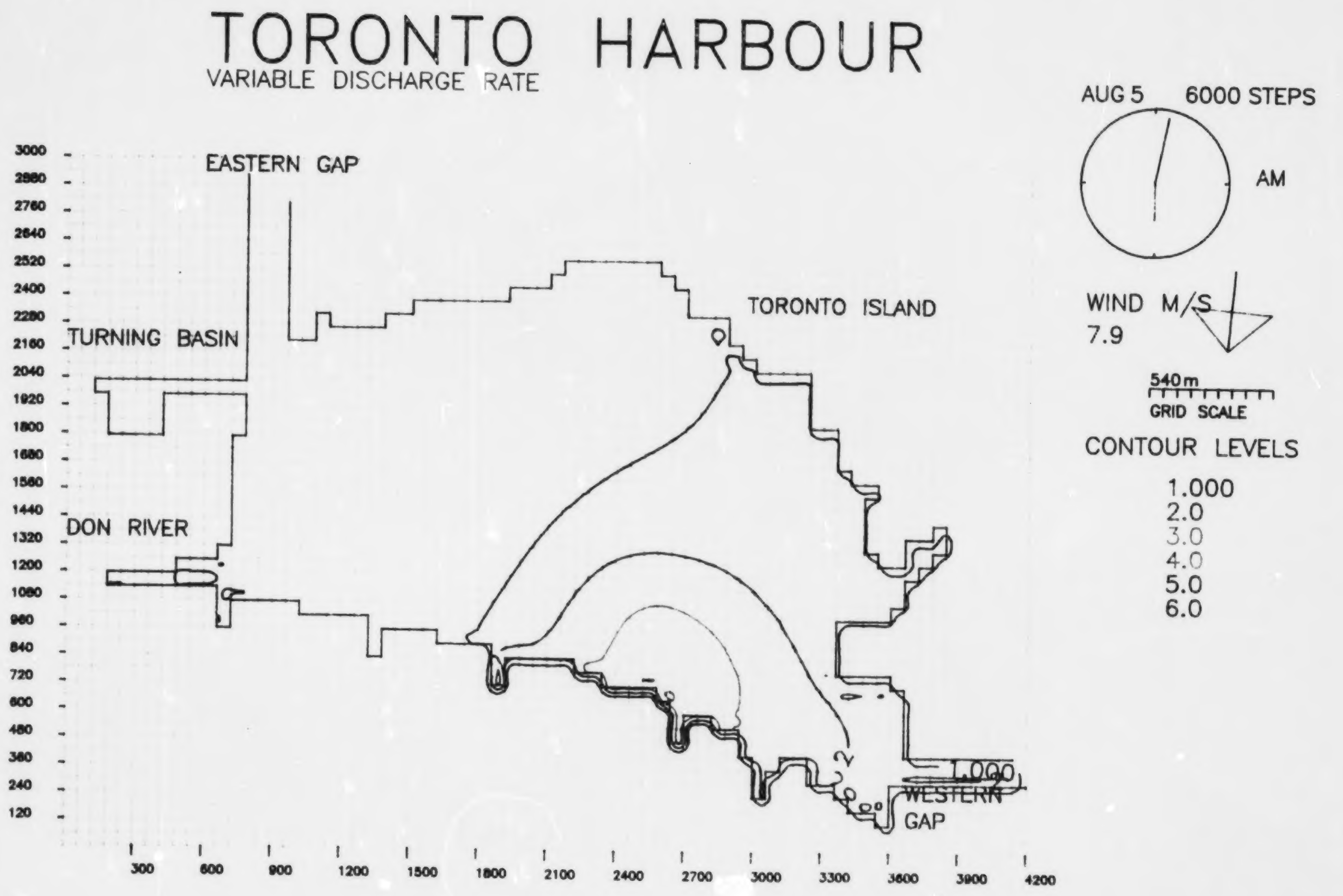
TORONTO HARBOUR
VARIABLE DISCHARGE RATE
AUG 5 6000 STEPS
AM
WIND M/S
7.9
540m
GRID SCALE
CONTOUR LEVELS
1.000
2.0
3.0
4.0
5.0
6.0
EASTERN GAP
TURNING BASIN
DON RIVER
TORONTO ISLAND
WESTERN GAP
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Figure 7A

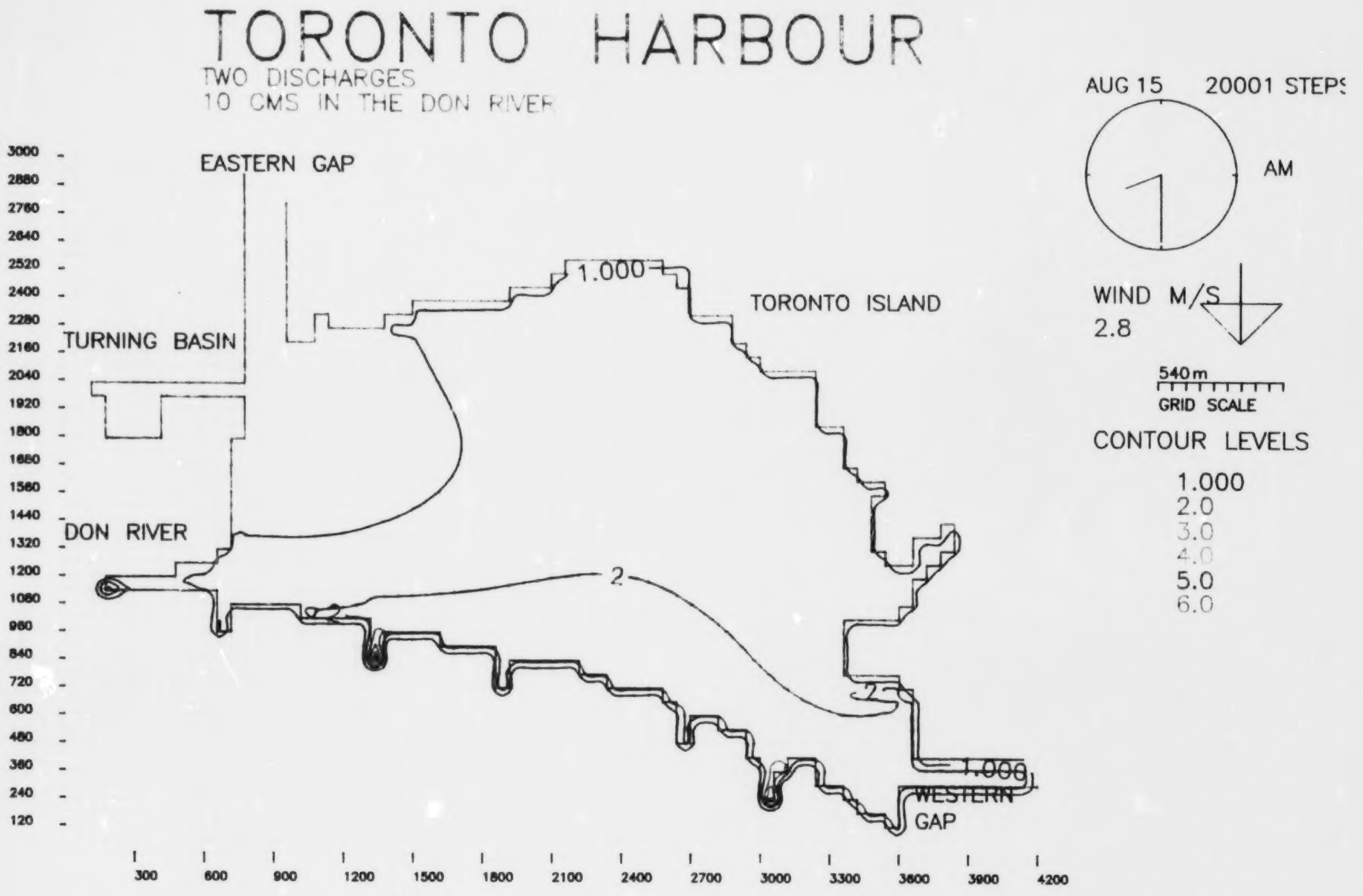
TORONTO HARBOUR
TWO DISCHARGES
10 CMS IN THE DON RIVER
AUG 15
20001 STEPS
AM
WIND M/S
2.8
540m
GRID SCALE
CONTOUR LEVELS
1.000
2.0
3.0
4.0
5.0
6.0
EASTERN GAP
TURNING BASIN
DON RIVER
TORONTO ISLAND
WESTERN GAP
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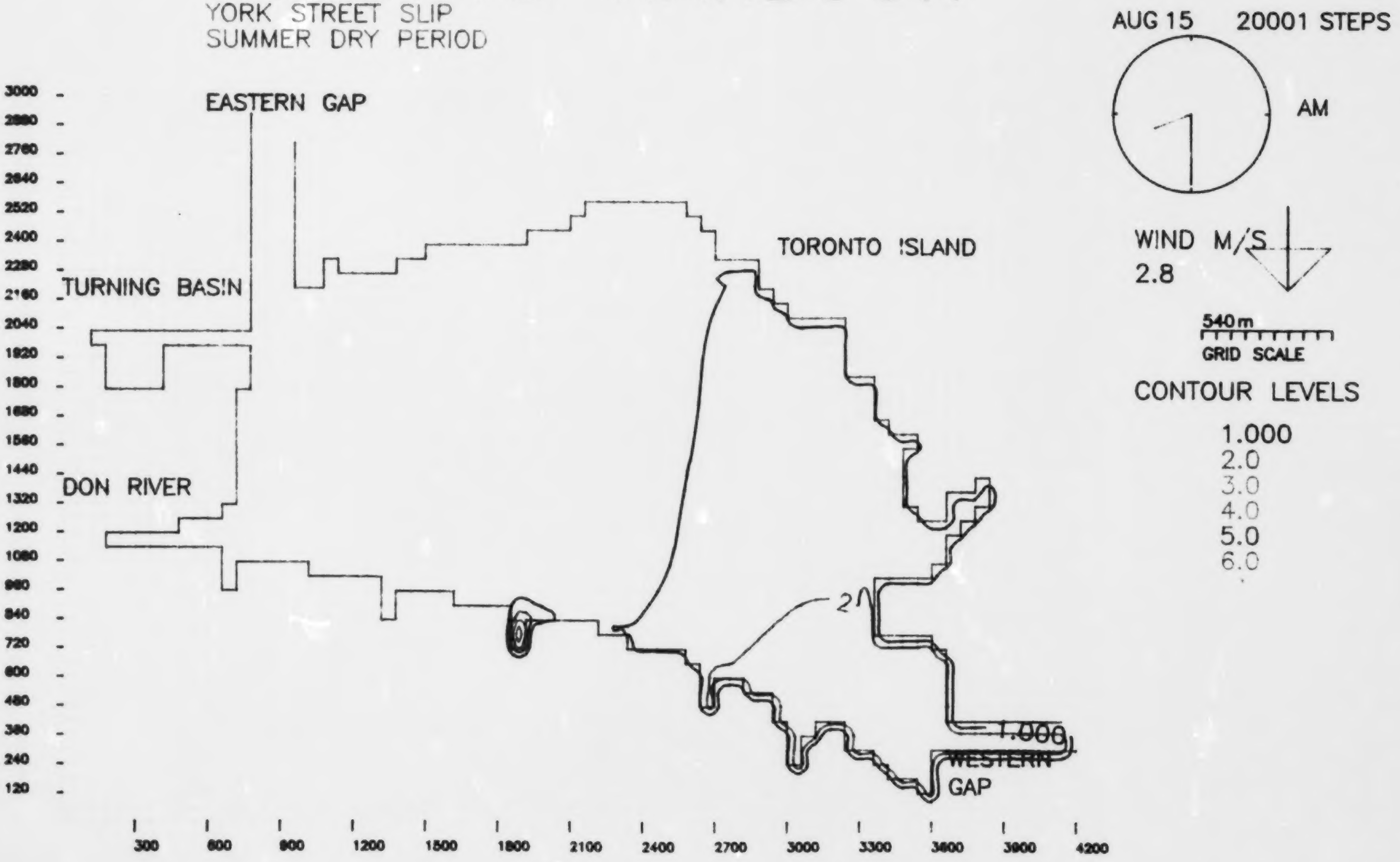
FIGURE 16B

TORONTO HARBOUR

YORK STREET SLIP
SUMMER DRY PERIOD


AUG 15
20001 STEPS
AM
WIND M/S
2.8
540m
GRID SCALE
CONTOUR LEVELS
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2.0
3.0
4.0
5.0
6.0
EASTERN GAP
TURNING BASIN
DON RIVER
TORONTO ISLAND
WESTERN GAP
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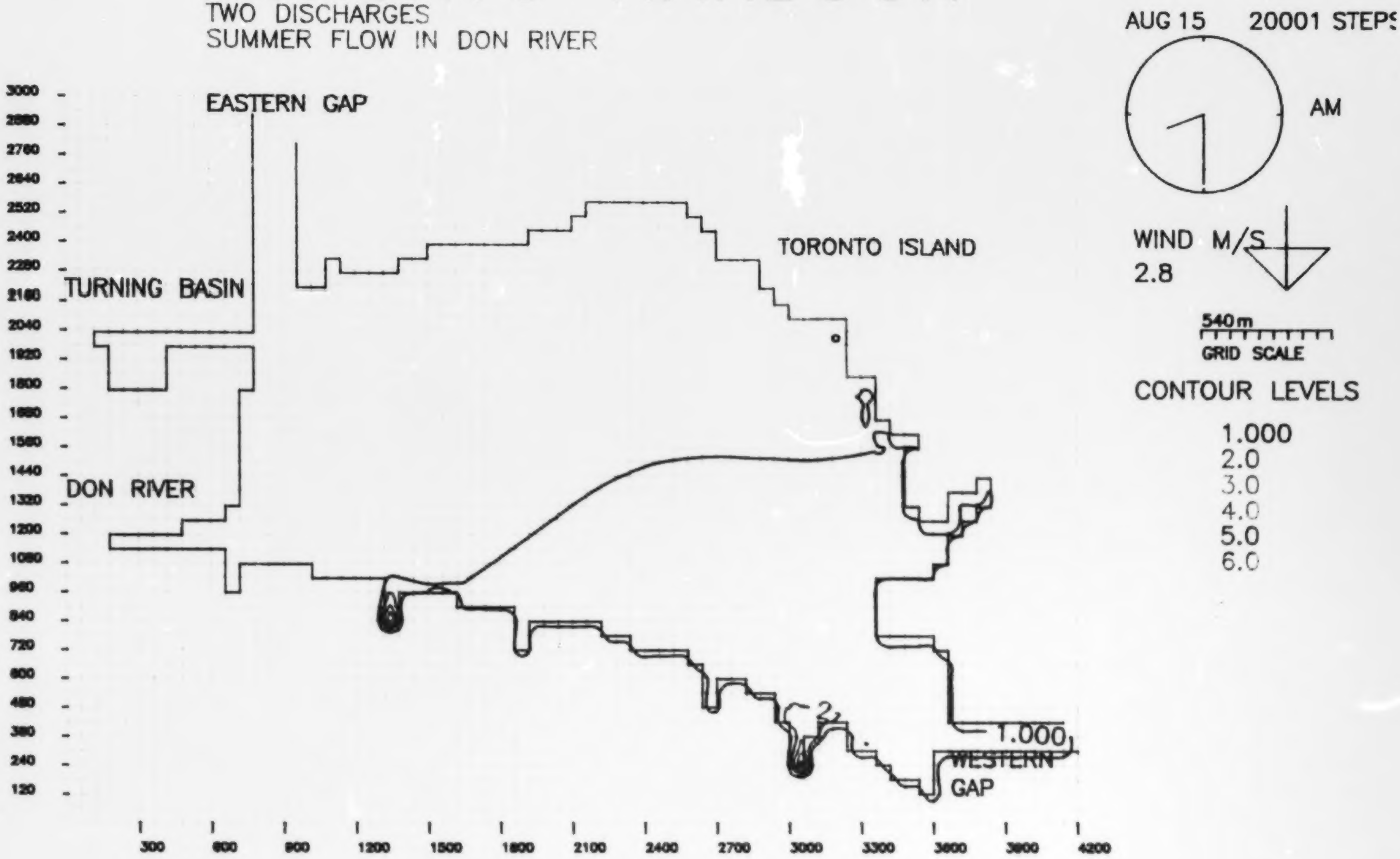
FIGURE 71

TORONTO HARBOUR

TWO DISCHARGES
SUMMER FLOW IN DON RIVER


AUG 15
20001 STEPS
AM
WIND M/S
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540m
GRID SCALE
CONTOUR LEVELS
1.000
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6.0
EASTERN GAP
TURNING BASIN
DON RIVER
TORONTO ISLAND
WESTERN GAP
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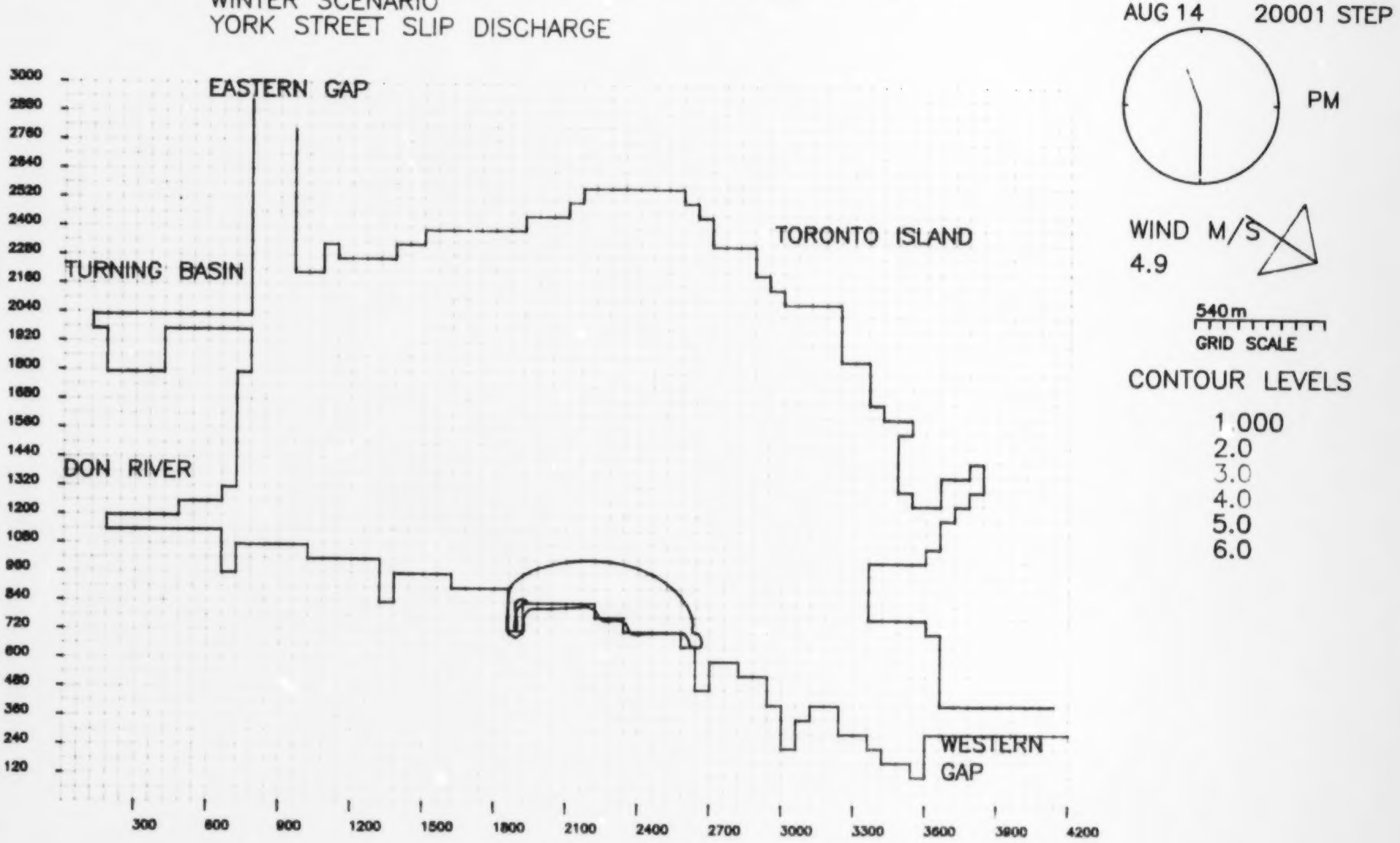
FIGURE 81

TORONTO HARBOUR

WINTER SCENARIO
YORK STREET SLIP DISCHARGE



AUG 14
20001 STEP
PM
WIND M/S
4.9
540m
GRID SCALE
CONTOUR LEVELS
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EASTERN GAP
TURNING BASIN
DON RIVER
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WESTERN GAP
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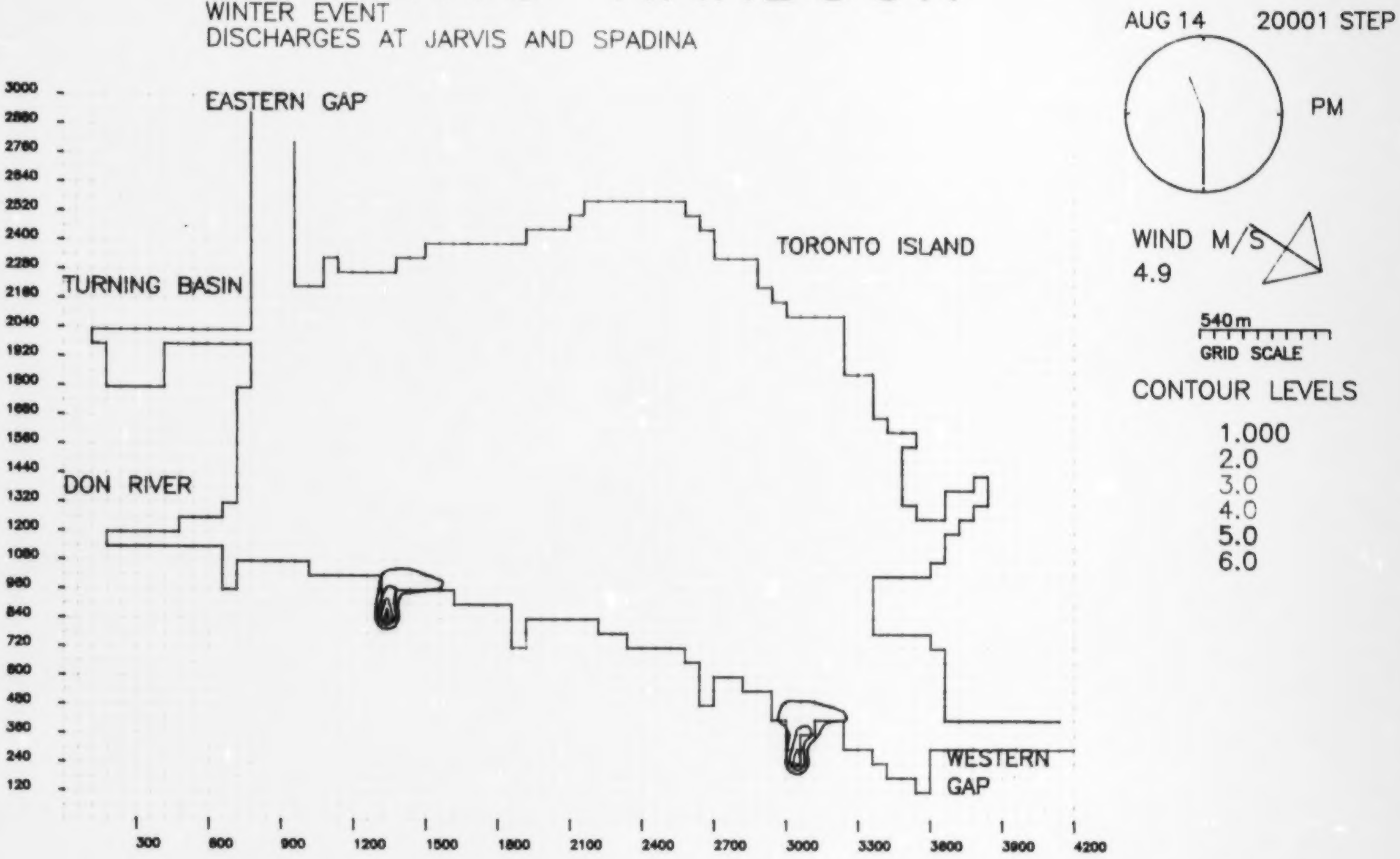
Figure 5

TORONTO HARBOUR

WINTER EVENT
DISCHARGES AT JARVIS AND SPADINA


AUG 14
20001 STEP
PM
WIND M/S
4.9
540 m
GRID SCALE
CONTOUR LEVELS
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EASTERN GAP
TURNING BASIN
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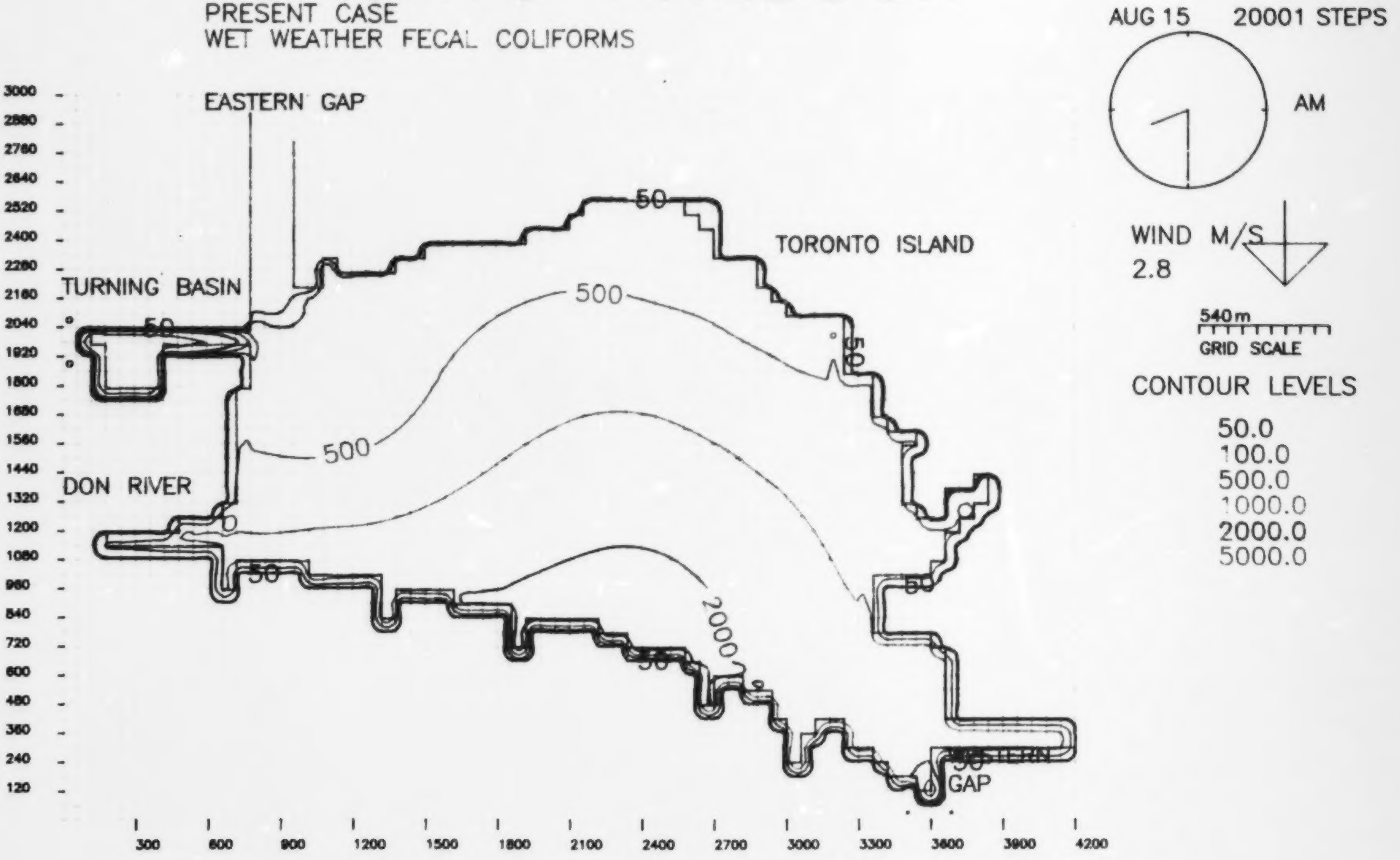
Figure 6

TORONTO HARBOUR

PRESENT CASE
WET WEATHER FECAL COLIFORMS


AUG 15
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GRID SCALE
CONTOUR LEVELS
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EASTERN GAP
TURNING BASIN
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TORONTO ISLAND
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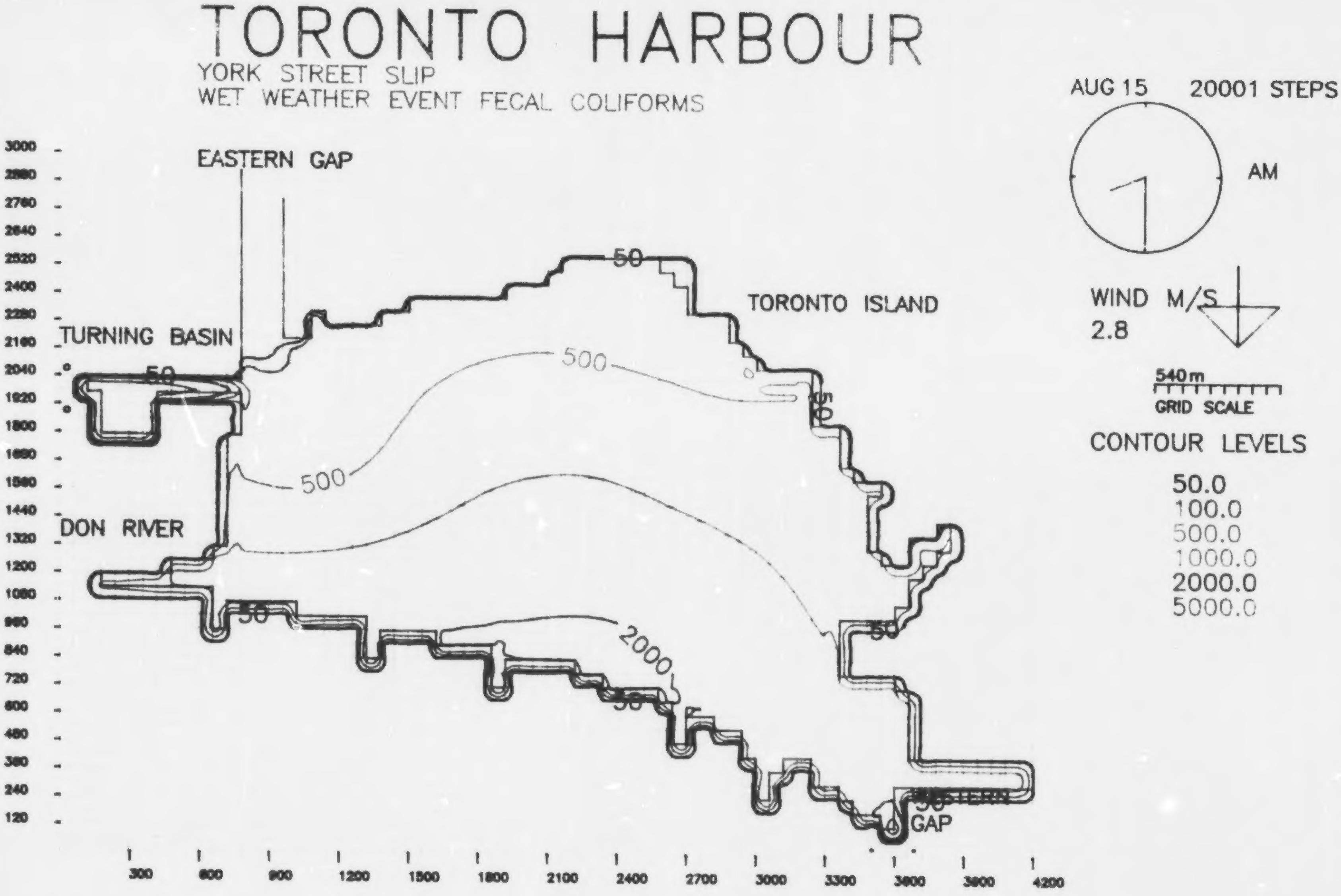
FIGURE 15B



TORONTO HARBOUR

YORK STREET SLIP
WET WEATHER EVENT FECAL COLIFORMS

AUG 15 20001 STEPS

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GRID SCALE
CONTOUR LEVELS
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EASTERN GAP
TURNING BASIN
DON RIVER
TORONTO ISLAND
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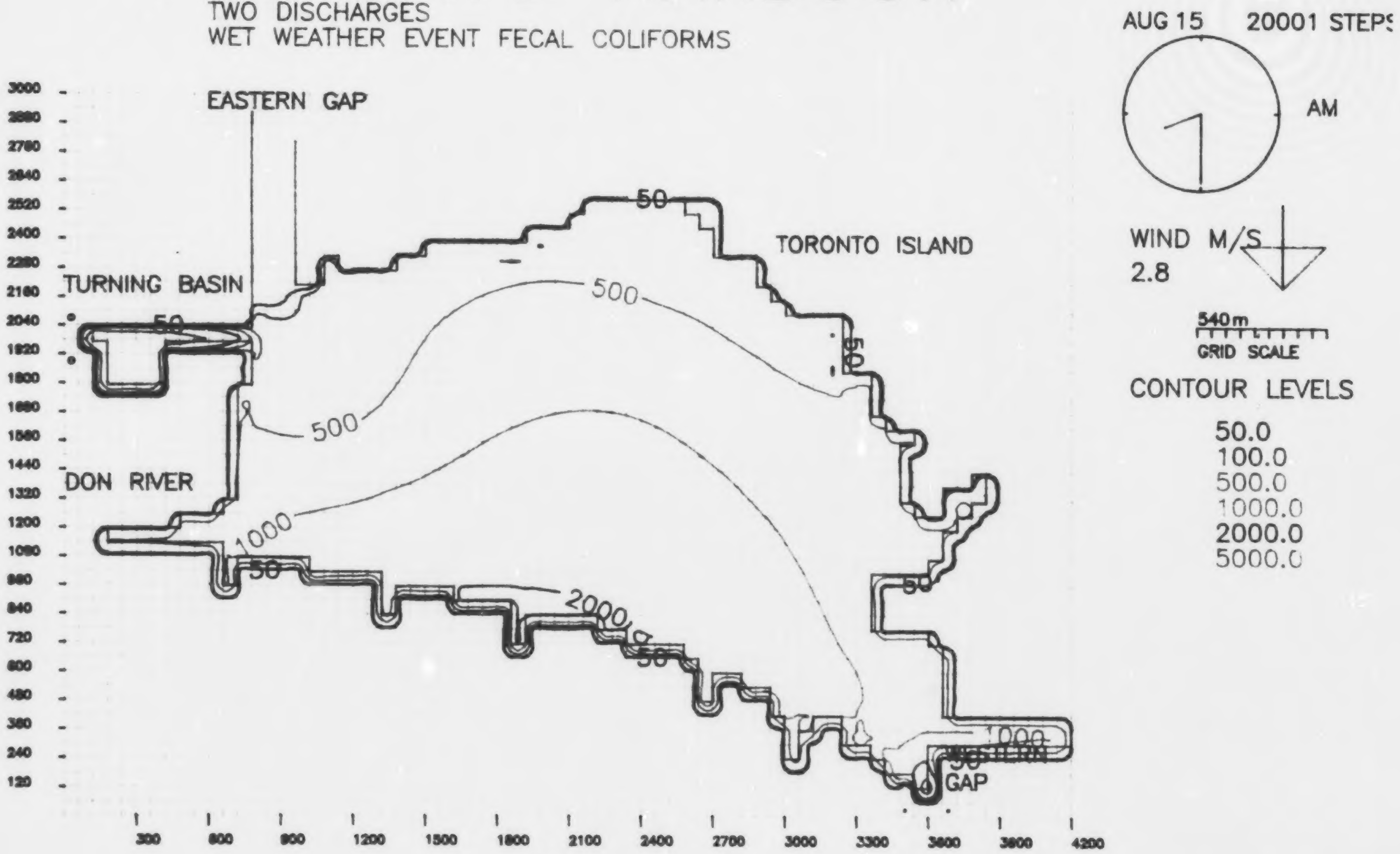
FIGURE 9B

TORONTO HARBOUR

TWO DISCHARGES
WET WEATHER EVENT FECAL COLIFORMS



AUG 15 20001 STEP
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CONTOUR LEVELS
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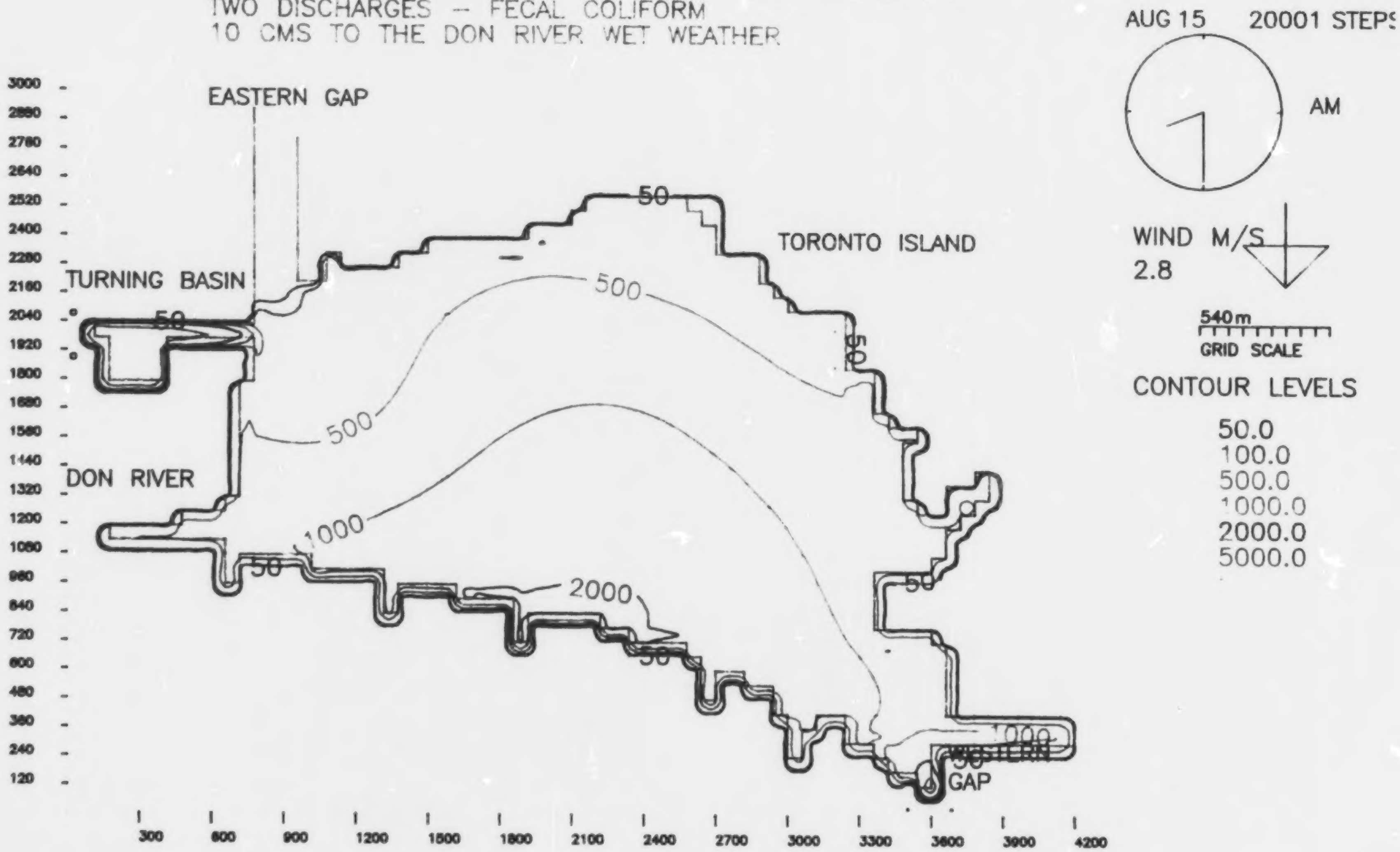
FIGURE 10B

TORONTO HARBOUR

TWO DISCHARGES -- FECAL COLIFORM
10 CMS TO THE DON RIVER WET WEATHER


AUG 15
20001 STEPS
AM
EASTERN GAP
TORONTO ISLAND
TURNING BASIN
DON RIVER
WESTERN GAP
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WIND M/S
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GRID SCALE
CONTOUR LEVELS
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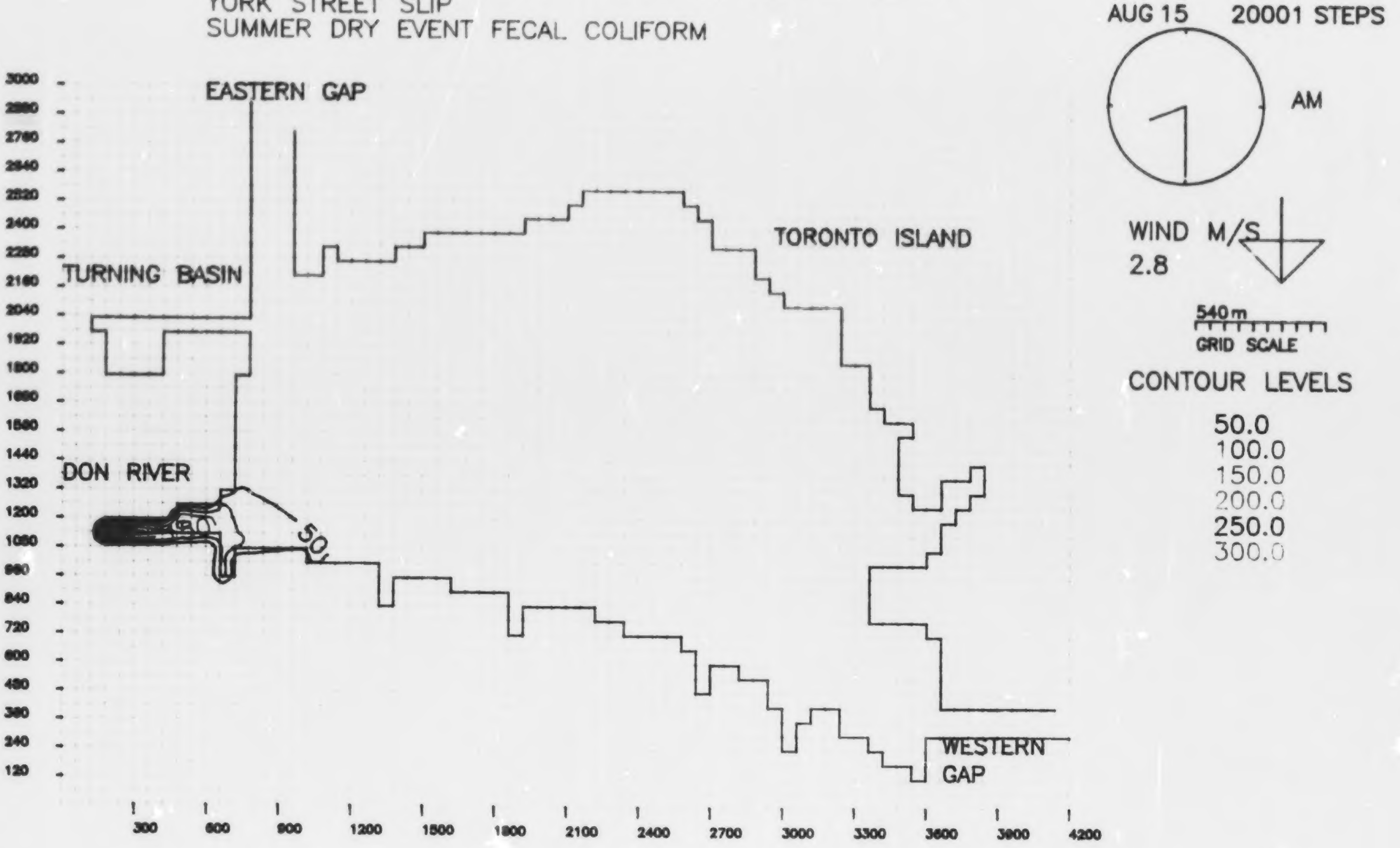
FIGURE 17B

TORONTO HARBOUR

YORK STREET SLIP
SUMMER DRY EVENT FECAL COLIFORM


AUG 15
20001 STEPS
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WIND M/S
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540m
GRID SCALE
CONTOUR LEVELS
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EASTERN GAP
TURNING BASIN
DON RIVER
TORONTO ISLAND
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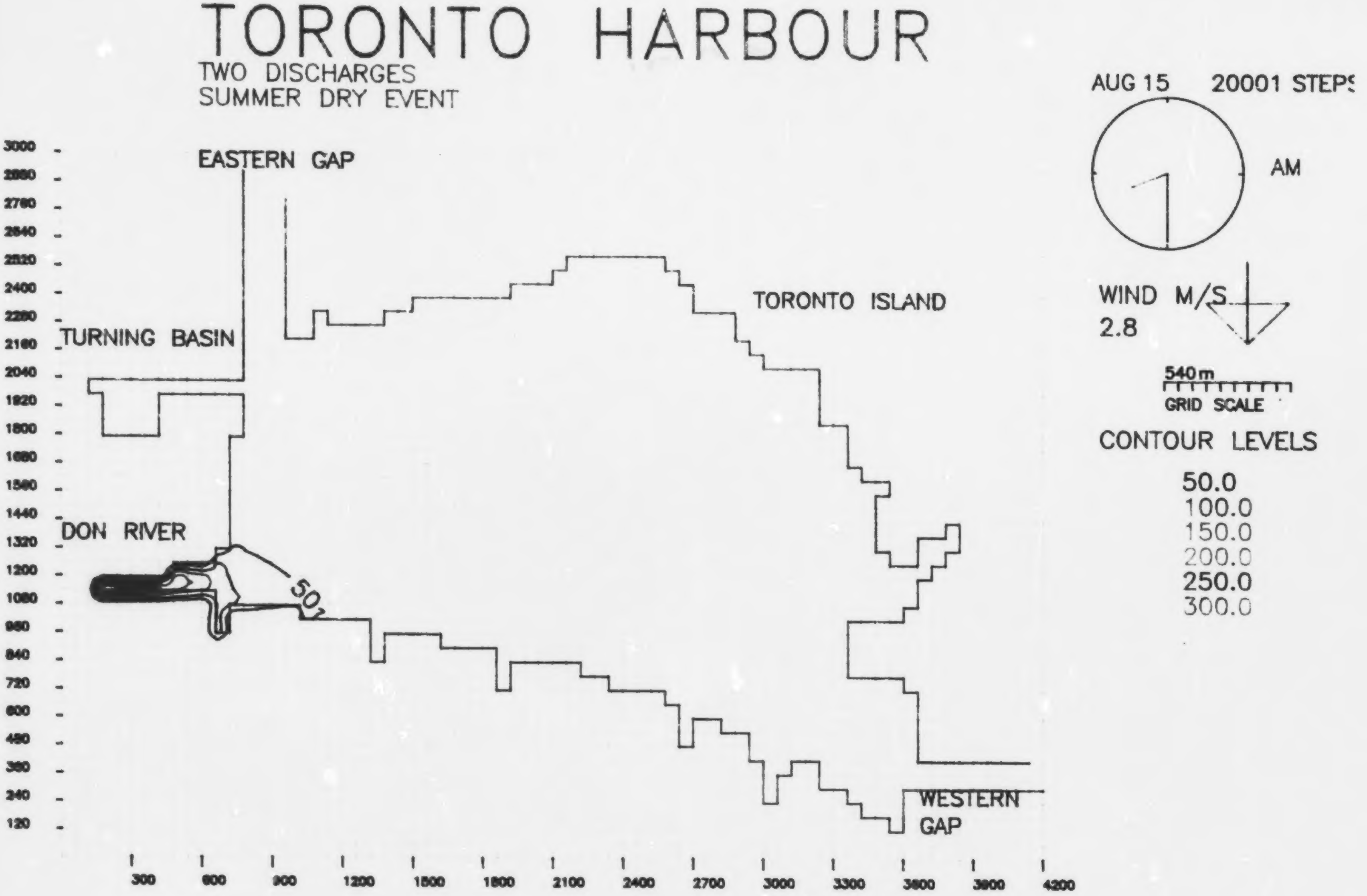
FIGURE 12B


TORONTO HARBOUR
TWO DISCHARGES
SUMMER DRY EVENT
AUG 15
20001 STEPS
AM
WIND M/S
2.8
540m
GRID SCALE
CONTOUR LEVELS
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EASTERN GAP
TURNING BASIN
DON RIVER
TORONTO ISLAND
WESTERN GAP
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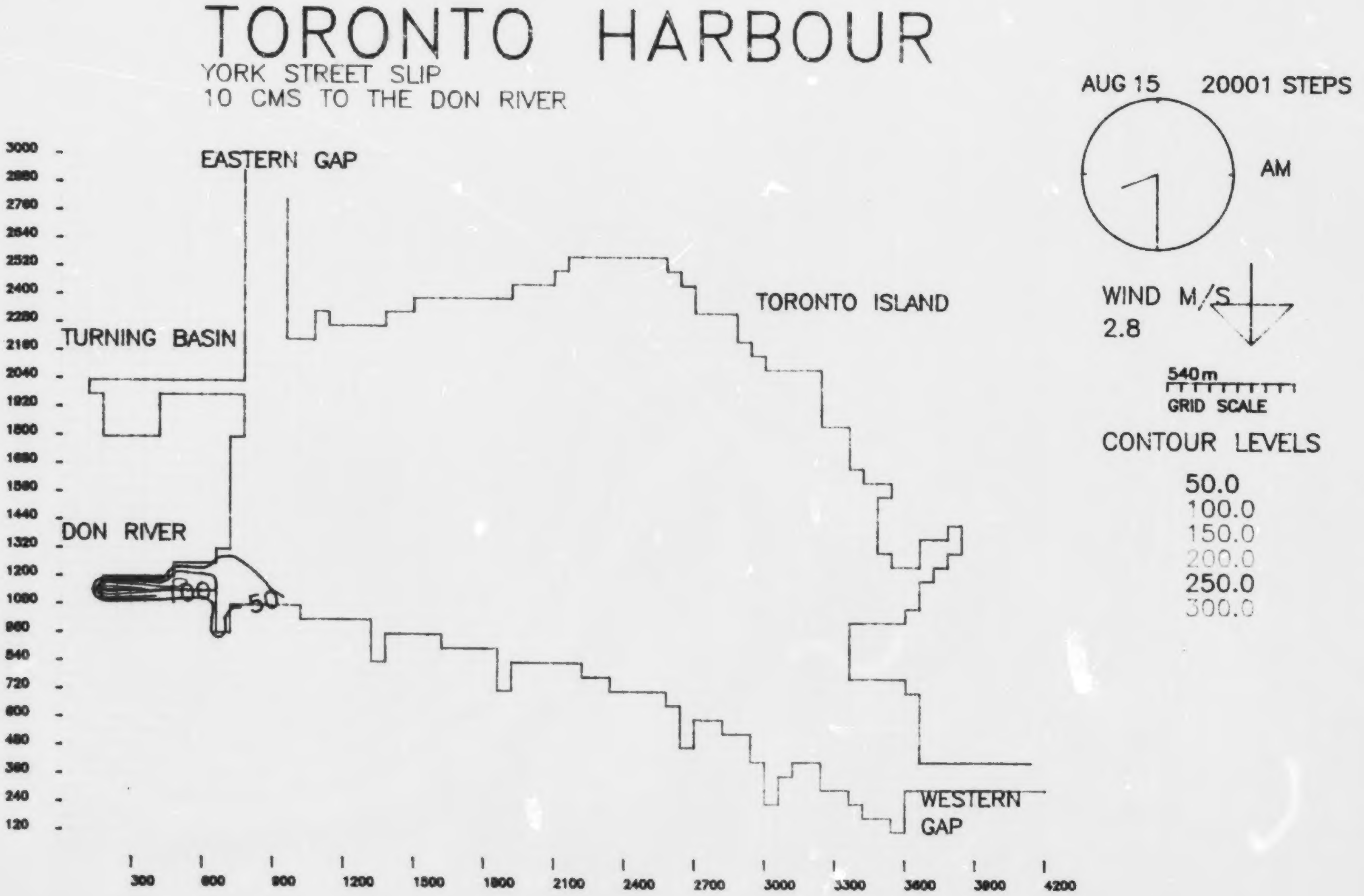
FIGURE 13B


TORONTO HARBOUR
YORK STREET SLIP
10 CMS TO THE DON RIVER
AUG 15
20001 STEPS
AM
WIND M/S
2.8
540m
GRID SCALE
CONTOUR LEVELS
50.0
100.0
150.0
200.0
250.0
300.0
EASTERN GAP
TURNING BASIN
DON RIVER
TORONTO ISLAND
WESTERN GAP
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3300
3600
3900
4200

FIGURE 14B

4.0 COOLING WATER INTAKE CONSIDERATIONS

4.1 General

The major requirement of the Deep Lake Water Cooling System Project is the withdrawal of hypolimnion water from Lake Ontario to act as a source of cooling for buildings in the City of Toronto downtown core. One of the major considerations, both from an engineering design feasibility, as well as an environmental prospective, is the continuous availability of cold water in the lake. From an environmental point of view, there is concern that the hypolimnion water will be adversely affected by the withdrawal, either in terms of the quantity available for biota, or its quality after significant quantities have been withdrawn.

A review of August and September CCIW Water Quality Monitoring Program Data from 1989 and 1990 indicates that off-shore stations recording 90 metres depth document water temperatures between 4° and 5°C; dissolved oxygen values at approximately 13 parts per million (99 to 102% saturation) with pH in the range of 7.7 and conductivities in the range of 300 microsiemens (specific conductance at 25°C). Light penetration at this depth approaches zero.

4.2 Withdrawal from Hypolimnion

Preliminary calculations that were undertaken by staff at the Lake Research Branch, National Water Research Institute in Burlington, Ontario indicate that concerns about depletion of the hypolimnion from the withdrawal of cooling water are essentially unfounded. The off-shore hypolimnion of Lake Ontario at 100 metres depth and lower has been estimated conservatively to occupy an area of approximately 9,000 square kilometres. If approximately 1.4 x 10^8 cubic metres were withdrawn from this layer annually, it would result in a decrease of approximately 0.016 metres in depth. The Institute observes that, "on a lake wide basis, this is a very small fraction of the observed year to year variation", in the thickness of the hypolimnion through natural processes. It is noted that the calculations do not take into account that turnover of lake waters occurs and that some recharging of the hypolimnion occurs in the spring and autumn.

Based on these calculations, as long as the proposed intake is designed to minimize vertical intake flows, and given that the intake structure will be located in 80 metres of depth, one can be reasonably assured that disturbances to natural thermal stratification and the quantity of hypolimnion water available to biota will not be significantly affected by implementing the deep water cooling concept.

An ancillary concern in this regard has been the potential impact of internal seiches resulting from surface wind effects on thermally stratified water. Traditionally, Lake Ontario has been subject to internal seiches which might approximate the maximum displacement of two to three metres at one end of the lake or the other (depending on the fetch and duration of surface winds). It is clear from this, however, that intake pipes at 80 metres depth (conservatively, 60 metres below the limit of thermocline) would not be subject to any negative effects due to seiches.

Information on the Fisheries Communities of the benthic areas of Lake Ontario is limited. Most of the review of literature and environmental research that has been undertaken in this regard has occurred through the normal monitoring of government agencies involved with international waters, or through the specific work of Ontario Hydro in their environmental impact evaluation of lake side power plants. Hydro intake facilities are much closer to shore and in the much shallower water, typically 20 m or less. The fish communities in shore are generally more varied in species composition and have higher local densities. With this in mind, it has been the general conclusion of Ontario Hydro that intakes do not have a significant effect on lake wide fish communities and any disturbance is very localized. There has, however, been some problem with fish being drawn into the Hydro intakes. As a result, the factors concerning the operation of such facilities have attempted to deal with entrainment and impingement by designed mitigation. At the in-shore locations of Hydro intake structures, it has been suggested that the benthic/demersal communities may benefit from the physical habitat opportunities presented by the intake structures.

The fish communities that would exist at 6 km off-shore, in 80 metres or more of water, are not well documented. The very low temperatures (4°C) and the very low light levels probably represent conditions unsuitable for many species. For example, the widely distributed alewife exhibits a lower lethal temperature limit of 3.5°C. Also a number of wide range pelagic and benthic species have recorded a significant decline in populations, or have been extirpated from the lake in the last century. One can presume that the benthic fish community inhabiting depths of 80 metres or more, will not be represented by high densities or diverse assemblages.

The testing by Ontario Hydro (1984) on fish species inhabiting in-shore areas indicates that typically fish cue visually, or sense a difference in water pressure from current and eddy effects. At 80 metres depth, visual cuing from traditional bottom dwelling species is not anticipated. Design provisions can be made to reduce the velocity of intake waters such that the fish are warned of the presence of intakes without being captured by strong currents (15 to 30 cm/s). Specific design of intake orifices can also be utilized to reduce fish capture.

It is not anticipated that the construction material was used for intake structures, or the disturbance of sediments, will produce any long term effects through contamination or disturbance. Tunnelling will have a minimum disturbance of the benthic sediments. Benthic sediments at 6 km distance from shore are not anticipated to have significant contaminant concentrations.

Subject to further more detailed analysis, and a wider review of the available literature on this potential problem, it is safe to say that the amount of hypolimnion water in Lake Ontario should not be significantly affected by withdrawals for cooling in the orders of magnitude estimated in a EIL design concept. In addition, given the developments Hydro has made to intakes to minimize environmental impacts of intake structures, it is reasonable to conclude that any thermal stratification in the locale of the intake pipe will not be influenced or affected by the proposed concept, nor will entrainment of fish and other aquatic life forms be significant.

4.3 Potential Environmental Considerations

The major environmental issues at the intake at a depth of approximately 80 metres, roughly six km off shore concern possible local impacts on benthos, fisheries and sediments. A preliminary assessment indicates that the impact on local benthos will be highly localized, involving a very small area on the lake bed. The intake structures and ancillary works will almost certainly involve less than 1,000 square metres in area. Although there is little current information on the specific benthic communities and substrate of the area of Lake Ontario where the intake structure may be located, it is safe to say that the populations of benthic species are not particularly unique, rare, or sensitive. The displacement or removal of benthic organisms over such a local and limited area is not anticipated to have any impact on the benthic environment of that area of the lake, and certainly not the lake as a whole. Mitigation measures and environmentally sound construction techniques can be adopted if and when detail design and construction proceeds.

4.4 Intake Options

Proctor and Redfern have identified 3 types of intakes which provide a reasonable range of options for the proposal:

1) tunnel for the entire length of the pipe;
2) excavated trench for part of the length and tunnel for the balance;
3) excavated trench for the entire length.

Environmental factors were not explicitly used in the evaluation of the 3 options, as such was not part of their Terms of Reference. Our initial review of the options indicates that the most appropriate scheme from an environmental perspective coincides with the Proctor and Redfern recommendation.

Excavated trench involves considerably more surface substrate disturbance. With this option, sediments are disrupted and in-shore, the potential for contaminant mobilization exists. There would be more disruption to benthos and to keep water fisheries, although the latter may benefit from habitat opportunities resulting from bottom structure diversity from excavated spoil.

In general environmental terms, the relatively limited environmental condition changes anticipated from the intake pipe (in the context of the large area of the lake greater than 80 m in depth) favour a tunnel construction through the native shale.

4.5 Conclusions

An initial review of the available literature and preliminary calculations indicate that there will be no significant impact on the integrity of thermal stratification or the amount of hypolimnion water from the Deep Water Lake Cooling Project.

Any displacement of benthos will be local. Benthic and deep water pelagic fish communities should experience little impact. In any case, design mitigation measures can be adopted to reduce the probability of entrainment and impingement (capture) at the intake.

More work on deep water benthic biota should be undertaken. Additional investigation of design options for intakes located in deep waters should also be explored.

5.0 HYDRO DISPLACEMENT EMISSIONS BENEFITS

5.1 General

The Deep Lake Water Cooling concept has the potential to significantly reduce the consumption of electric power in the downtown core during the summer, and consequently, to reduce the emissions associated with the power that would have been generated using fossil fuels.

Since building cooling load maximums tend to coincide with peak load periods for Ontario Hydro, one hypothesis concludes that with deep water cooling in lieu of electric chillers, the reduction in demand during peak periods will directly reduce the use of fossil fuel generated power, since such stations are operated by Hydro as peaking plants, unless base load facilities such as nuclear and hydro power are out of service. Discussions with Ontario Hydro, however, indicate that the direct link of peak demand to fossil fuel plants is not as straightforward as it may seem. Therefore, the following discussion of fossil fuel emission reduction due to deep water cooling assumes that only 50% of the power reduction realized can be related to fossil fuel generating stations. With a more definitive analysis of the predicted reduction of power due to deep water cooling over the year, and during each day, in subsequent studies Ontario Hydro should identify how much of the reduced peak should be allocated to a reduction of their fossil fired facilities output. Further, with respect to fossil fuel plant emissions reduction, Ontario Hydro have indicated that it may be that by the time deep water cooling is implemented (the year 2000±), Hydro may not be utilizing coal fired facilities.

5.2 Emissions Reduction Potential

A conservative calculation of the annual reduction of power consumed in Toronto's downtown core due to the lake water cooling concept yields a reduction of 293,000 MWh/year. With the assumptions that 50% of this power will reduce the output required from coal fuel fired plants, the associated emissions reductions were calculated and are presented in Table 5.1.

Table 5.1 - Emissions Reductions with Deep Lake Water Cooling
(Tonnes/year) [Ref. 5.4.1, 5.4.2, 5.4.3]

CO_2	146,000
SO_2	1,285
NO	320
Particulate	36
Fly Ash Collected	3,677

The above corresponds to the displacement of 55,000 tonnes of coal.

To provide some perspective on the significance of potential reduction of carbon dioxide (CO_2), Table 5.2 provides a comparison of various CO_2 emission sources.

Table 5.2 - CO_2 Generation Rates Comparison
(Tonnes/year)

Ontario Total	170,000,000	[Ref. 5.4.4]
Ontario Hydro Coal Fired Plants Total	28,000,000	[Ref. 5.4.1, 5.4.2]
City of Toronto Total	2,400,000	[Ref. 5.4.5]
City of Toronto Electrical(1)	768,000	[Ref. 5.4.5]
Deep Lake Water Cooling Reduction Potential	146,000	
One Family Car	5	[Ref. 5.4.6]

(1) Assuming 24.4% of City electric power derived from fossil fuel fired generating stations.

5.3 Other Greenhouse Gas Benefits

Although it is generally accepted that carbon dioxide is the major contributor to the Greenhouse effect, there are other gases also contributing to the global warming. Those relevant to this study would be other products of coal combustion such as methane (CH_4) and nitrous oxide (N_2O), and the two most common chlorofluorocarbons (CFC) refrigerants, R-11 and R-12.

Methane and nitrous oxide are not major emissions from coal firing (7.7 kg and 155 kg, respectively, per MWhr elect) when compared with CO_2 (1000 kg per MWhr elect), however, their effectiveness as greenhouse gases are considerably greater than CO_2. With CO_2 at a level of 1, the effectiveness factors of CH_4 and N_2O are 25 and 250, respectively, and therefore reduction of these gases will also be beneficial.

CFCs, more commonly known as the destroyers of ozone, are also very effective greenhouse gases. On the same basis (CO_2 = 1), R-11 and R-12 have effectiveness factors of 17,500 and 20,000 respectively. There will be a major change in refrigerants over the next ten years from CFCs to HCFCs (R-123) and HFCs (R-134a) to reduce the destruction of ozone and their effectiveness as greenhouse gases will also reduce.

R-123 is intended to replace R-11 and the reduction in ozone destruction capability and greenhouse gas effectiveness are expected to be 2% of R-11. R-134a, replacing R-12, will have no effect on ozone as it contains no chlorine and the greenhouse effectiveness is expected to be 10% of R-12.

Assuming that 10% of the current refrigerants leak from chillers providing 300,000 tons of cooling, it is estimated that 27,000 kg of R-11 (the most common CFC) would discharge to the atmosphere which, as a greenhouse gas, is equal to 475,000 tons/yr of CO_2. However, replacement of R-11 with R-123 would reduce the CO_2 equivalence to approximately 9500 tonnes/yr.

An alternative to compressor-type refrigerant cycles is the use of absorption chillers. Absorption chillers use either lithium bromide or ammonia as the heat transfer medium and use heat as the energy driver. The benefits of absorption chillers with respect to the greenhouse effect are that there are no CFCs and much less electric power is required. Conversion of centrifugal chillers to absorption chillers would eliminate many of the environmental benefits that deep lake water cooling offer, however, economics might restrict the acceptance of absorption chillers.

5.4 References

5.4.1 Acid Gas Emissions from Ontario Hydro Fossil Fuel-Fired Thermal Generating Station, December 1990, CPS-07120-0002, February 5, 1991.

5.4.2 Energy Related Carbon Dioxide Emissions in Alberta, 1988 to 2005, Alberta Energy, Energy Efficiency Branch.

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5.4.7 Greenhouse Gas Emissions from the Operation of Energy Facilities, P.H. Gleick, G.P. Morris, N.A. Norman, July 22, 1989. Prepared for the Independent Energy Producers Association, Sacramento, CA.

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6.0 LOCAL AIR QUALITY STUDIES

6.1 General

The urban heat island is a well documented phenomenon (Landsberg, 1981). The heat island is caused by complex interactions between many factors including decreased urban albedo, increased thermal mass per unit area, increased city roughness, increased anthropogenic heat release from buildings and vehicles and decreased evaporative areas (less trees and more impervious materials). All these factors influence the energy (temperature) and moisture balance in urban areas (Oke, 1978; Myrup, 1969), and can generate beneficial as well as detrimental effects, depending on the season, location, latitude, physical characteristics and the amount of anthropogenic heat in a city.

The reduction in urban moisture increases the local Bowen Ratio (ratio of sensible to latent heat flux) which leads to higher ambient temperatures. In a cool climate, the heat island is an asset, since it will reduce high winter heat loads (Thurow, 1983). However, during hot summers, the heat island contributes to the urban dwellers discomfort and energy consumption, due to increased cooling loads.

The complexity of the urban island is further increased when the city is situated near a large water body. In Toronto, the lakeshore acts as an immediate change in surface roughness, temperature and evaporation, to which low-level air flow must react. In a shoreline environment, the existence of local circulations, commonly known as lake/land breezes, is well documented. These local circulations develop in response to differential heating and cooling at the land/water interface. During the daytime, the land surface temperature rises rapidly due to incoming solar radiation, whereas the water temperature stays almost constant (due to its large heat capacity). The resulting pressure gradient sets up a circulation cell with onshore winds at lower levels and return flow at upper levels. This process is reversed during the night-time, with land cooling rapidly to a lower temperature than that of the neighbouring water body. The development of lake/land breezes may modify the local flow pattern such that meteorological data collected at inland sites, or sites in other shoreline environments, are non-representative.

Onshore flow during the daytime may bring a stable air mass from over the water onto a rapidly heating land mass. As the cooler air mass moves inland, it is heated from below and a convective bounding-layer develops which is called the Thermal Internal Boundary-Layer (TIBL). This phenomenon is further enhanced in an urban environment where the heating from below is at a greater rate. Plumes which are released into the upper stable air mass are transported inland and become entrained in the deepening TIBL. The subsequent rapid mixing of the plume to the ground may persist for several hours and is referred to as continuous fumigation.

The Ontario Ministry of Environment (OME) has developed a shoreline fumigation model (Misra, 1980; Misra and Onlock, 1982) which is part of the proposed Clean Air Program (CAP) modelling system. The model parameter which determines the height of the boundary layer extent is found to be the most significant. This parameter is a function of the difference between land and lake temperatures.

The following meteorological conditions should be met if the shoreline fumigation models are to be applied:

1. The wind direction should be onshore within a 140° sector centred on a line perpendicular to the shoreline near the source.

2. Convective conditions are diagnosed to occur overland.

3. The hours to be modelled are within the time period between April 15 and October 15.

4. The land temperature is more than 3°C higher than the lake temperature.

With the Deep Water Cooling Concept, the lake temperature may increase while the ambient temperature will likely decrease over the area serviced by deep water cooling, due to a reduced heat output. This suggests that the frequency of shoreline fumigation might be reduced. The decrease in ambient moisture content with elimination of the evaporative coolers may result in an increased land temperature (less than 0.1°C). This effect will be inconsequential since these changes are expected to be very localized.

As the magnitude of the changes, in both the urban (land) and lake temperatures, are difficult to predict accurately, a sensitivity test of the model and frequency of potential shoreline fumigation was carried out. To assess the impact of shoreline fumigation on air quality over the City, two different fossil fuel fired boiler system stack heights, at two different locations within the City of Toronto, were compared under the following conditions:

i) current lake and urban ambient air temperatures,
ii) decrease ambient temperature or increase lake temperature by 1°C,
iii) decrease ambient temperature and increase lake temperature by 1°C.

A review of the CAP shoreline model is presented in Section 6.2 and an analysis of the shoreline meteorology is presented in Section 6.3. The results of the fumigation model when applied to generic cases are provided in Section 6.4. Conclusions and recommendations for future work are presented in Section 6.5.

6.2 Cap Shoreline Model

The CAP modelling system includes a shoreline fumigation model developed by Misra (1980) as part of the Nanticoke field study between 28 May to 14 June, 1979. The model results agree favourably with the observed values. A brief description of the model is presented.

Onshore flow of stable air (frequently stabilized by heat loss at the surface during advection over a relatively cold lake surface) to warm land surface heated by the sun creates conditions ideal for continuous fumigation of elevated contaminant releases. The thermal internal boundary layer which forms as a result of surface heating over land gradually deepens inland from the shore. Plumes which are released into the stable air near the shoreline can eventually be transported inland and become entrained in the deepening unstable TIBL. The rapid mixing of the plume to ground following its intersection with the TIBL may persist for several hours and is referred to as continuous fumigation.

A second dispersion regime which may occur for releases near a shoreline during onshore flow is plume trapping. Figure 6.1 illustrates fumigation and plume trapping in the thermal internal boundary layer.

All sources located within 15 kilometres of a major body of water are considered as potentially nearshore sources. Within a source complex, each source must be considered individually based on the release height of the source relative to the height of the TIBL. Observational studies have shown that the height of the boundary layer during onshore flow may be approximated as

$$\begin{aligned} H &= A(x + x_o)^{1/2} \, , \\ x_o &= h_o^2/A \, , \, and \end{aligned} \qquad [2.1]$$

$$A = \frac{u_*}{U_m}\left[\frac{T_L - T_W}{\Gamma}\right]^{1/2} . \qquad [2.2]$$

where H is the shoreline boundary layer height for onshore winds, x is the downwind distance from the shoreline, h_o is the shoreline boundary (defined as 50 m for non-urban and 100 m for urban settings), u_* is land surface friction velocity, U_m is the mean wind speed, Γ is the vertical temperature gradient (0.004°C/m) and T_L and T_W are the land and water temperatures, respectively. The parameter A is strongly dependent on the difference between lake and land temperatures, and may range between 1.5 and 6. The impact of the potential change in temperature due to Freecooling on the boundary layer height is evident in 2.1 and 2.2 as well as the frequency of potential occurrences of shoreline fumigation (i.e., $T_L - T_W \geq 3$°C).

Plumes released near the lakeshore will eventually intersect the TIBL at which point dispersion into the boundary layer is assumed to occur as from an area source located under the surface of the top of TIBL. The model assumes vertical and crosswind Gaussian distribution of the plume in the upper stable layer, and a uniform vertical distribution and Gaussian crosswind distribution of the plume in the internal boundary layer. For source release heights less than the local boundary layer height, the emissions are treated as if they are within a convective boundary-layer, but no allowance is made for plume penetration above the TIBL.

Further details are provided in Misra (1980) and OME (1990).

6.3 Shoreline Meteorology

The requisite meteorological data for the CAP shoreline model include hourly estimates of wind speed and direction, snowfall, cloud cover, ambient temperature and mixing height depth as well as monthly averaged lake temperature. Figure 6.2 presents the annual windrows for the Toronto area. (Lester B. Pearson International Airport hourly data were used because they were readily available in-house). The data are manipulated with the aid of a meteorological pre-processor to generate hourly estimates of atmospheric stability conditions as either neutral, stable or convective. Figure 6.3 presents the windrows for convective conditions in the Toronto area which occur 29% of the year.

Shoreline fumigation can occur only during convective conditions between the period of 15 April to 15 October, when the difference in ambient and lake temperatures is greater than 3°C and when the winds are blowing ±70° perpendicular to the shoreline. As the Toronto shoreline runs along a ENE-WSW line, the potential for shoreline fumigation is reduced to occurrences of winds from 75° to 255°. Figure 6.4 presents the windrows summary for potential shoreline fumigation on the City of Toronto (435 h per year).

Freecool has the potential for changing the ambient and lake temperatures by perhaps 1°C. This will affect the frequency of occurrence of potential shoreline fumigation as well as the extent of the TIBL. Figure 6.5 and 6.6 present the windrows summaries for potential shoreline fumigation with a -1°C change in land air temperature (or +1°C in lake temperature) and a 1°C change in both land (-1°C) and lake (+1°C) temperatures, respectively. The frequency of occurrence reduces from 5% (435 h) to 4.5% (399 h) and 4% (356 h), respectively.

As discussed above, the depth of TIBL is also affected by the potential land/lake temperature difference. The impact of the TIBL depth will vary from source to source within the city. This is reviewed in the following section.

6.4 Air Quality Impacts

The potential air quality impacts due to changes in the local ambient air (land) and lake temperatures were evaluated using the meteorology discussed in Section 6.3. To evaluate this impact, a generic 500,000 lb/hr steam gas-fired package boiler was modelled at two locations, each with two different stack heights. Table 6.1 presents the stack parameters used in the modelling study. One of the stacks was located at the shoreline, the other 2 km inland. Emission parameters and rates were based on typical operating conditions of gas-fired package boilers.

TABLE 6-1

Typical Stack and Emission Parameters
for 500,000 lb/hr Steam Gas-Fired Package Boiler

STACK PARAMETERS		
Height (m)	50	100
Diameter (m)	2.5	2.5
Velocity (m/s)	20	20
Temperature (°C)	200	200
NO_2 Emission Rate (g/s)	18	18

The primary contaminant from gas-fired package boilers is NO_2. This will be used as a surrogate for the means of comparison. Figures 6-7 to 6-9 present the cumulative frequency distribution (CFD) of ground-level NO_2 concentrations for the various temperature and stack scenarios.

The figures show that the ground-level concentrations CFD curves for the two stack heights are generally parallel to each other. For the current meteorological situation there is a significant reduction in ambient NO_2 concentrations between the shoreline stack location and 2 km in-land. At the shoreline (Figure 6-7a), the resultant concentrations are due to the intersection of the plumes with the TIBL and subsequent fumigation. At 2 km in-land (Figure 6-7b), the TIBL is likely sufficient in depth to trap the emissions within the TIBL and ground-level concentrations are modelled as if during convective conditions.

Figures 6-8a/8b present the CFD concentrations for the lake temperature +1° at shoreline and 2 km in-land. The maximum concentrations are the same for both scenarios but the frequency of higher concentrations increases for the higher lake temperature scenario. This is likely caused by an shallower TIBL, which the plume either intersects or is trapped beneath, than in the current scenario. The downward shift of the curve is evident for all scenarios.

The impact of a change in both land and lake temperatures is presented in Figure 6-9. Here, there is no change in the CFD concentration curves from the +1°C in lake temperature for the 50 m stack at either location or for the 100 m stack at 2 km away from the shoreline. The 100 m stack at the shoreline shows a small improvement in concentrations (i.e., a higher percentage of the time at a lower concentration). This would imply that the frequency of shallower TIBL's is reduced than the previous case.

6.5 Conclusions and Recommendations

The potential impact of implementing Deep Water Cooling on the Toronto downtown core air quality and meteorology has been reviewed on a preliminary level.

Generally, the potential for shoreline fumigation events is decreased if the lake temperature is increased or the land temperature is decreased. A further reduction occurs if both temperature changes occur simultaneously.

The height of the TIBL will also be reduced with the above changes and this could lead to an increase in the frequency of higher concentrations but the maximum level will likely not change.

It is expected that if the ambient temperature in the urban environment rises by more than 0.5°C due to deep water cooling and the associated decrease in humidity, the frequency of shoreline fumigation will increase. It is expected that the TIBL will thicken at a greater rate under this situation. The impact on the air quality will likely be a small increase in concentrations and frequency of events.

There will not be any detrimental or beneficial effect on the local shoreline climatology/meteorology or air quality due to deep water cooling if the temperature changes in the lake and land are a degree or less. Other sections of this report indicate such is the case.

It is recommended that if subsequent studies show greater changes in temperature, an acoustic radar system be located inland to measure the depth of the TIBL, as well as to determine frequency of occurrence. In addition, land and lake temperatures should be taken for subsequent model validation. A more detailed analysis can then be carried out using the measured data as well as wind speed and direction measured at the Toronto Island Airport.

6.6 References

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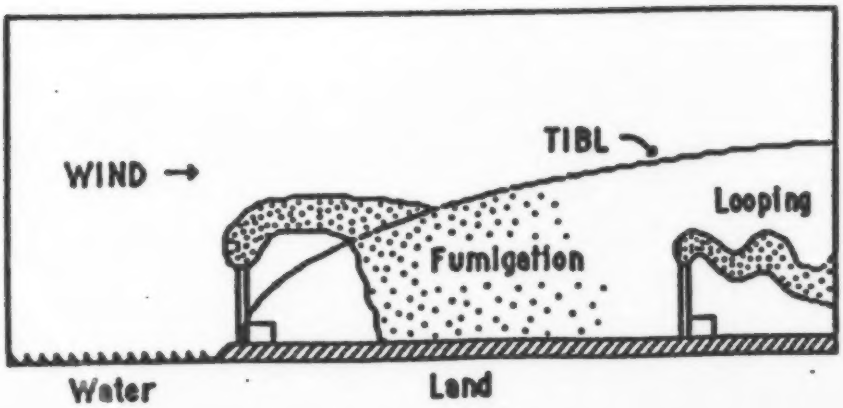
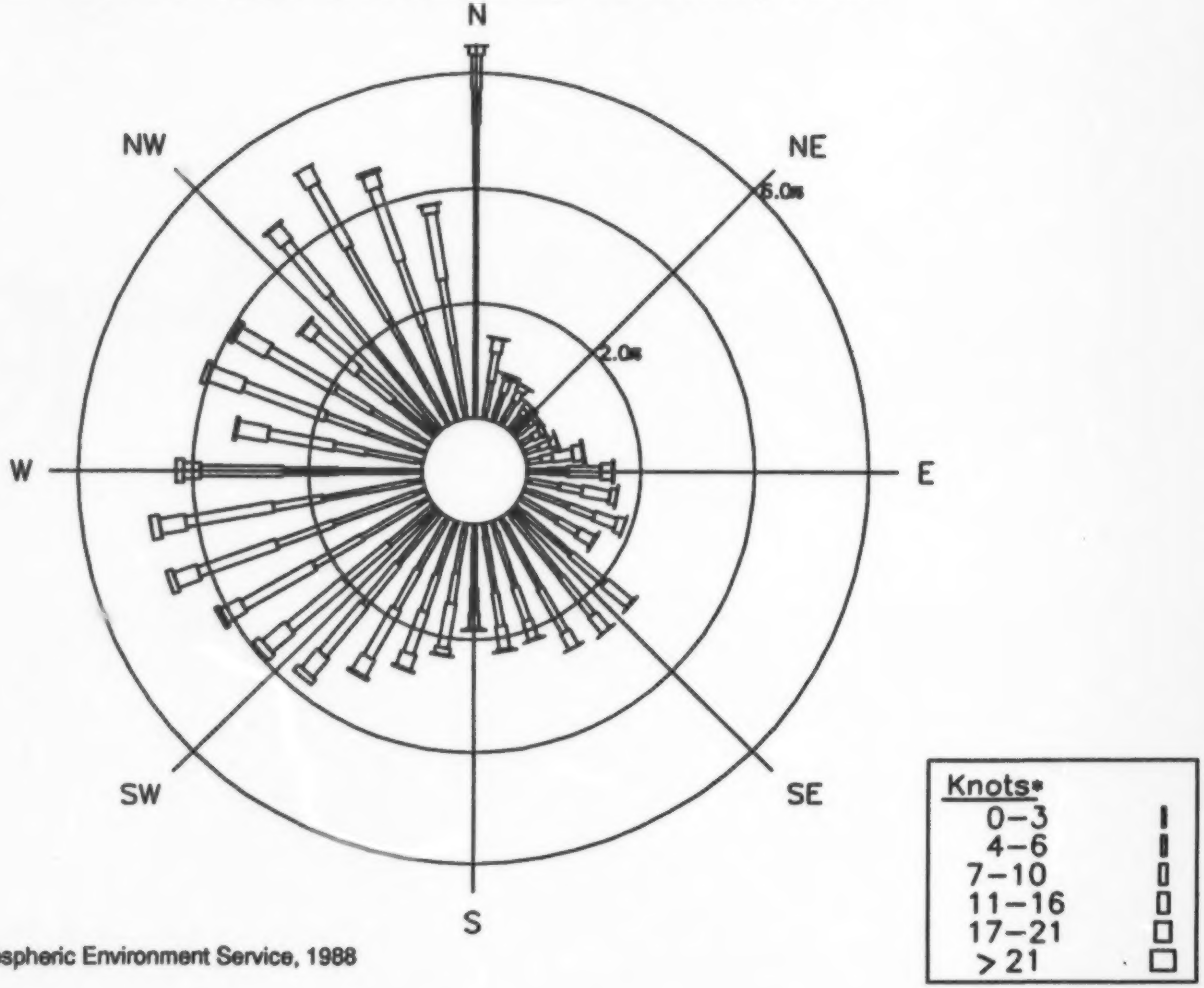

TIBL
WIND →
Looping
Fumigation
Water
Land

Plume behaviour on a sunny, spring day as a function of location relative to the thermal internal boundary layer (TIBL). The plumes emitted at the inland location essentially remains trapped within the TIBL (after Oke, 1978).

Fig. 6-1

Percentage Frequency of Wind Speed By Wind Direction for Annual Conditions, Toronto, 1988[1]

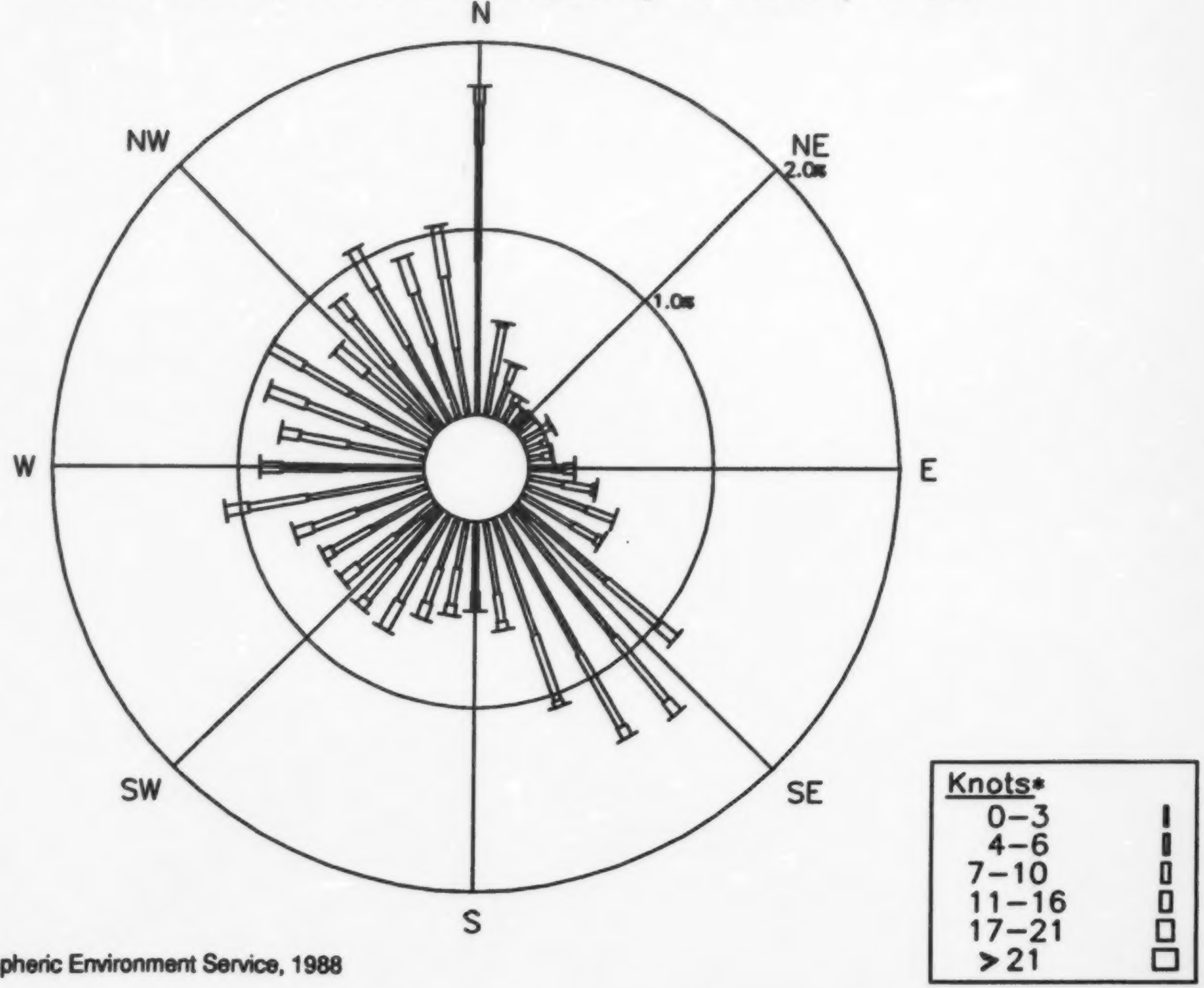


[1] Based on data from Atmospheric Environment Service, 1988

* 1 Knot = 1.85 km/h

Fig. 6-2

Percentage Frequency of Wind Speed By Wind Direction for Convective Conditions, Toronto, 1988[1]



[1] Based on data from Atmospheric Environment Service, 1988

* 1 Knot = 1.85 km/h

Fig. 6-3

Percentage Frequency of Wind Speed By Wind Direction for Shoreline Conditions, Toronto, 1988[1]

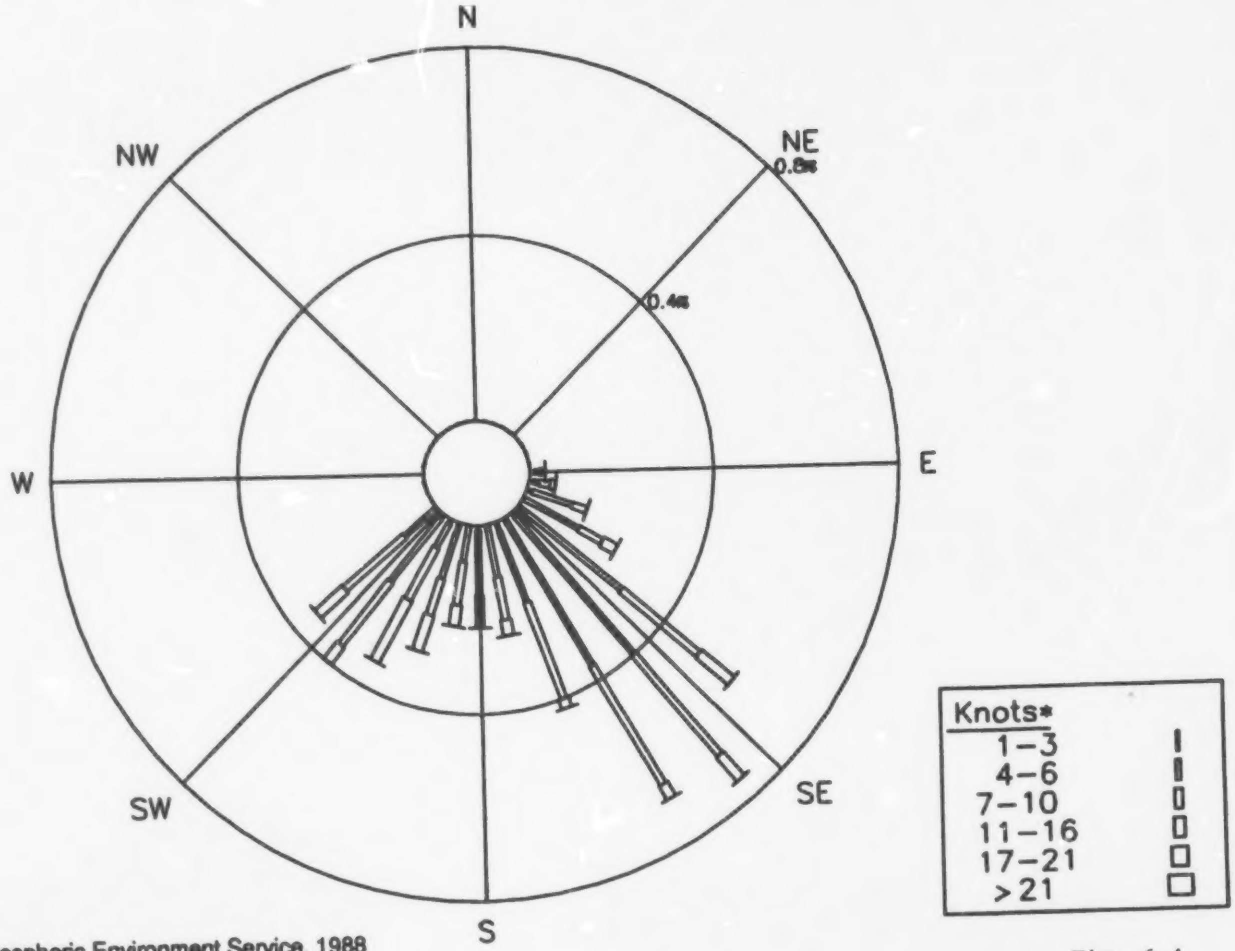
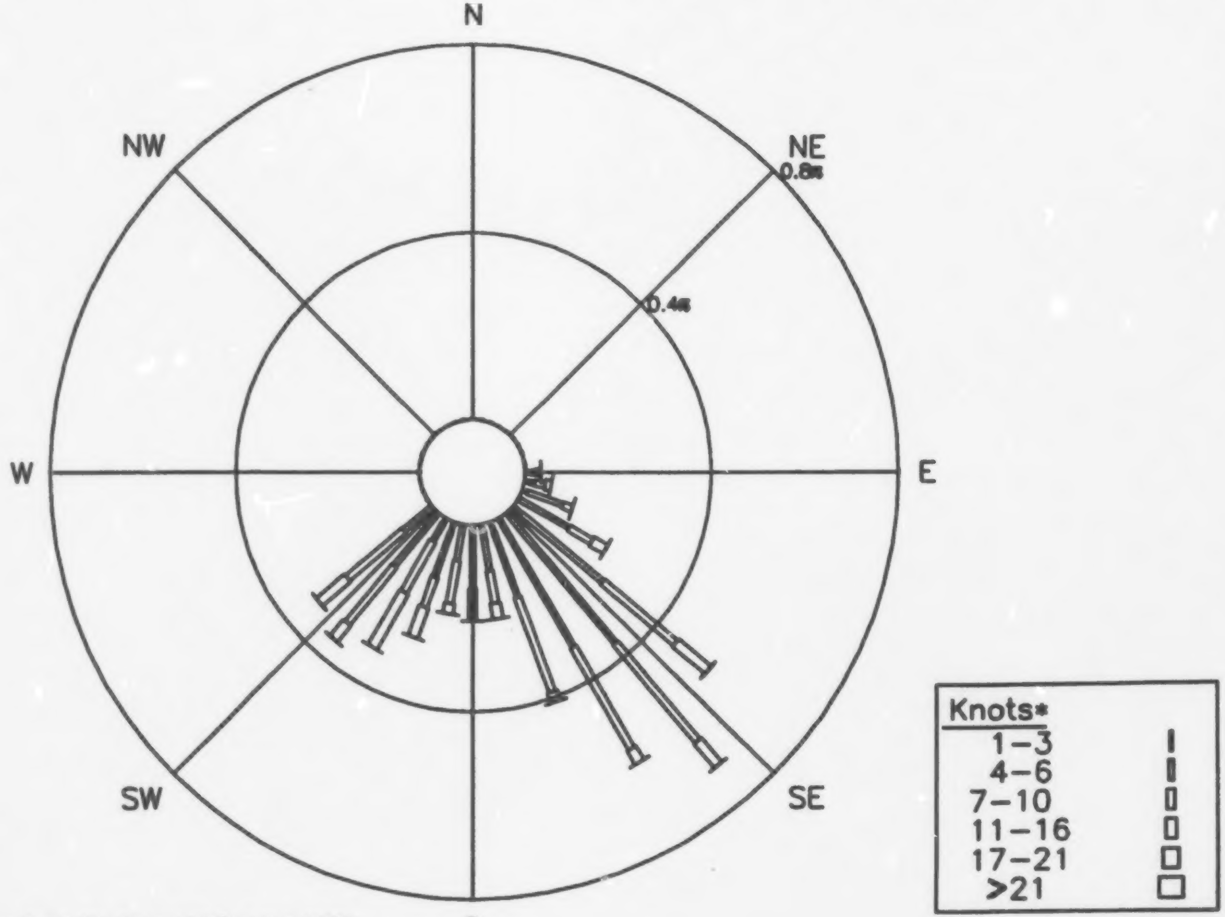


Fig. 6-4

1. Based on data from Atmospheric Environment Service, 1988

* 1 Knot = 1.85 km/h

Percentage Frequency of Wind Speed By Wind Direction for Shoreline Conditions (LAND -1 C), Toronto, 1988[1]



1. Based on data from Atmospheric Environment Service, 1988
* 1 Knot = 1.85 km/h

Fig. 6-5

Percentage Frequency of Wind Speed By Wind Direction for Shoreline Conditions (LAKE +1 C,LAND -1 C), Toronto, 1988[1]

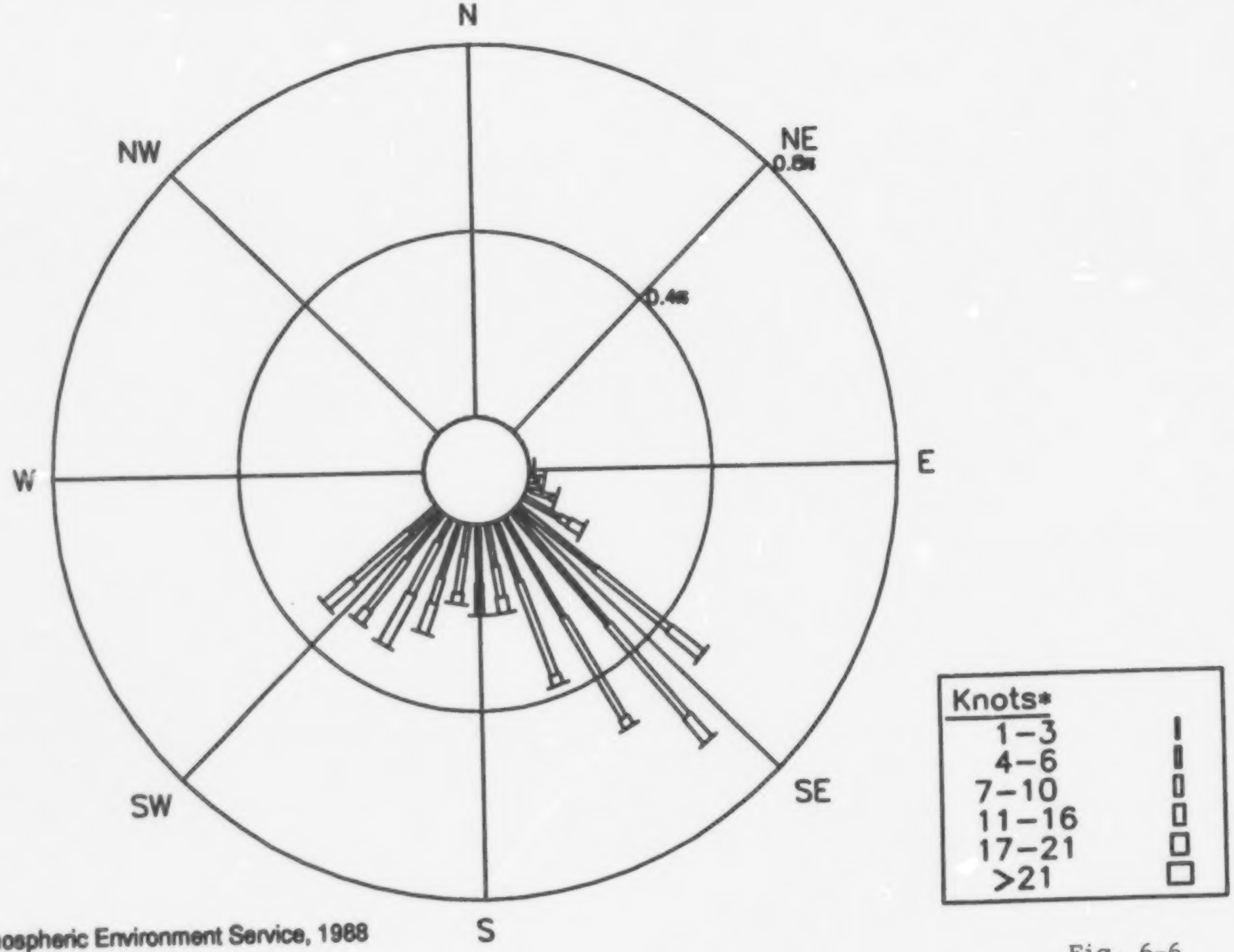


Fig. 6-6

[1] Based on data from Atmospheric Environment Service, 1988

* 1 Knot = 1.85 km/h

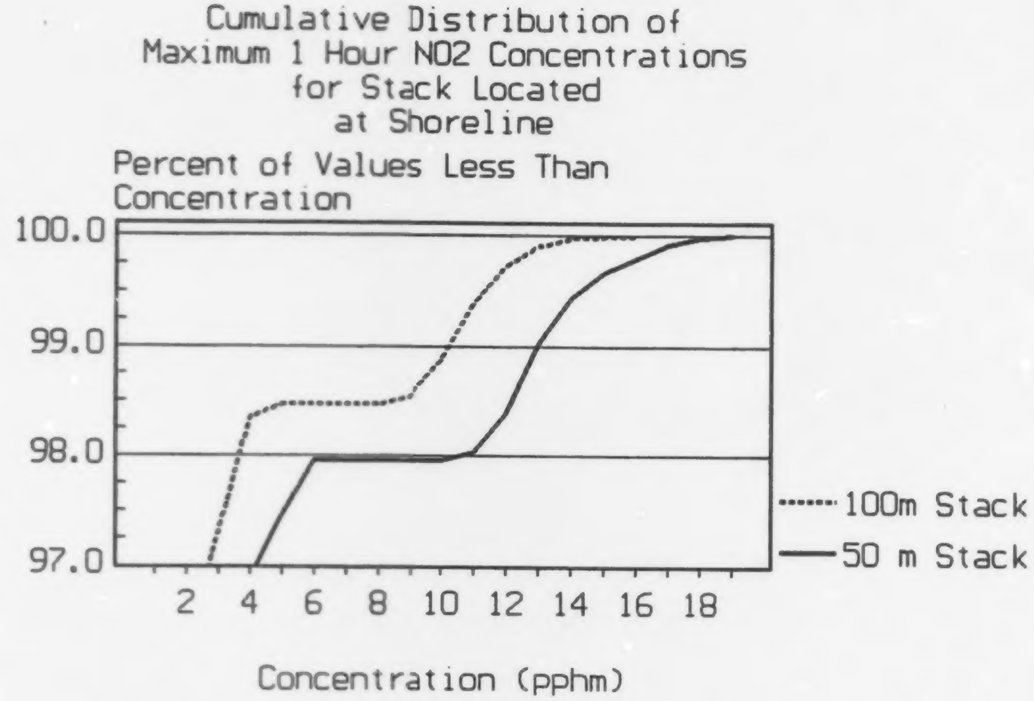


Fig. 6-7a

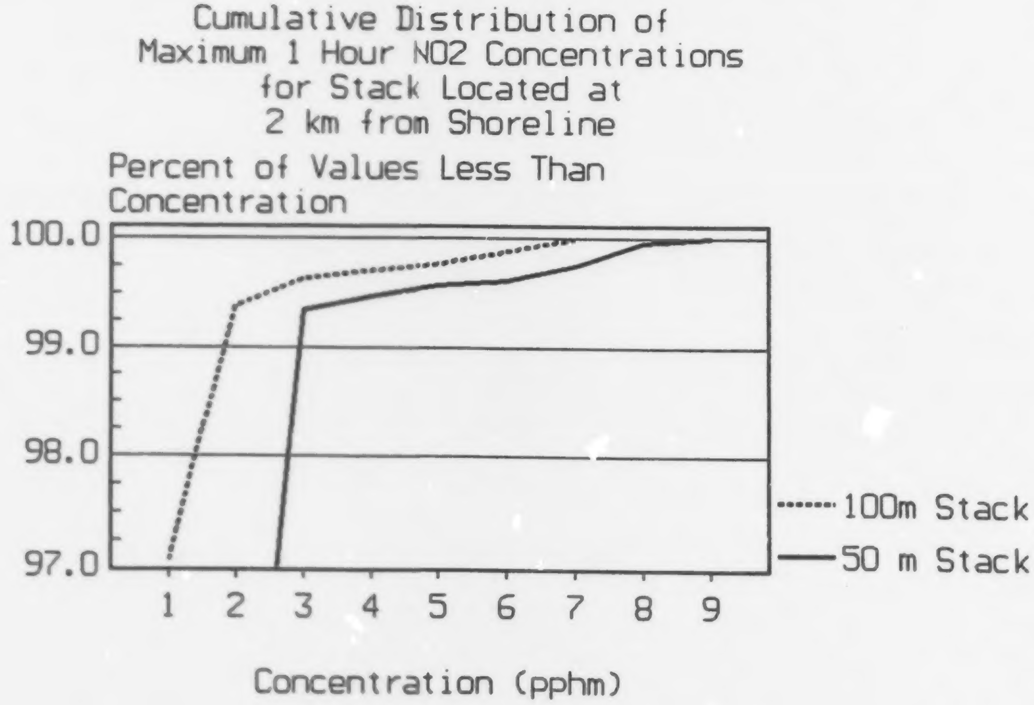
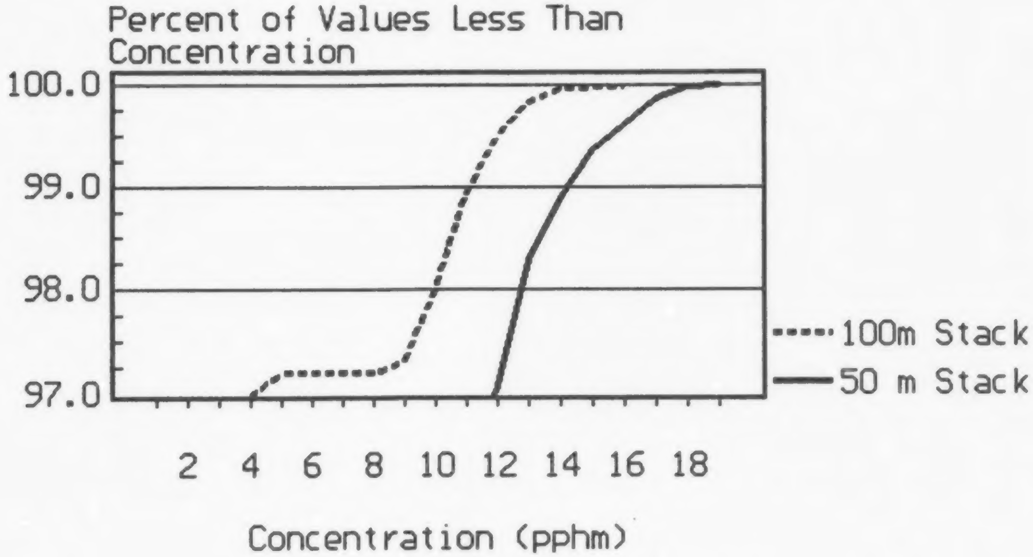
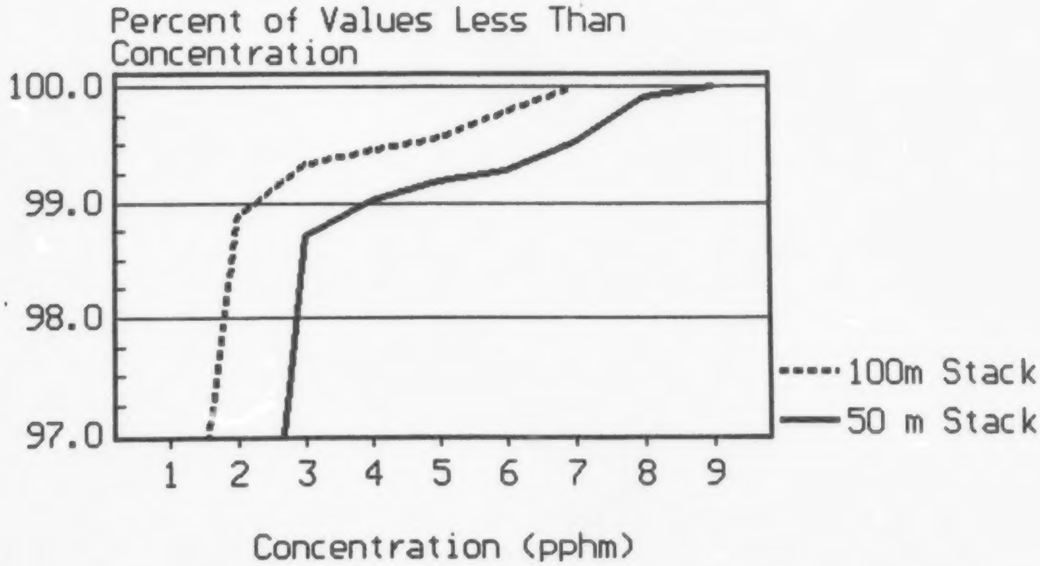


Fig. 6-7b



Cumulative Distribution of Maximum
1 Hour NO2 Concentrations for Stac
Located at Shoreline
Lake Temperature +1°C

Fig. 6-8a



Cumulative Distribution of Maximum
1 Hour NO2 Concentrations for Stack
Located at 2 km from Shoreline
Lake Temperature +1°C

Fig. 6-8b

Cumulative Distribution of Maximum
1 Hour NO2 Concentrations for Stack
Located at Shoreline
Lake Temp. +1°C, Land Temp. -1°C

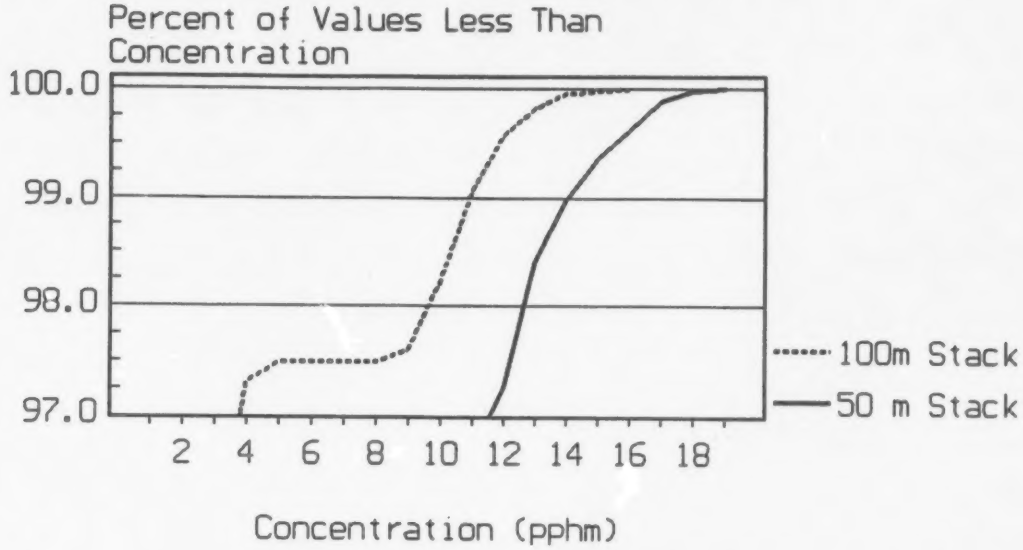


Fig. 6-9a

Cumulative Distribution of Maximum
1 Hour NO2 Concentrations at Stack
Located at 2 km from Shoreline
Lake Temp. +1°C, Land Temp. -1°C

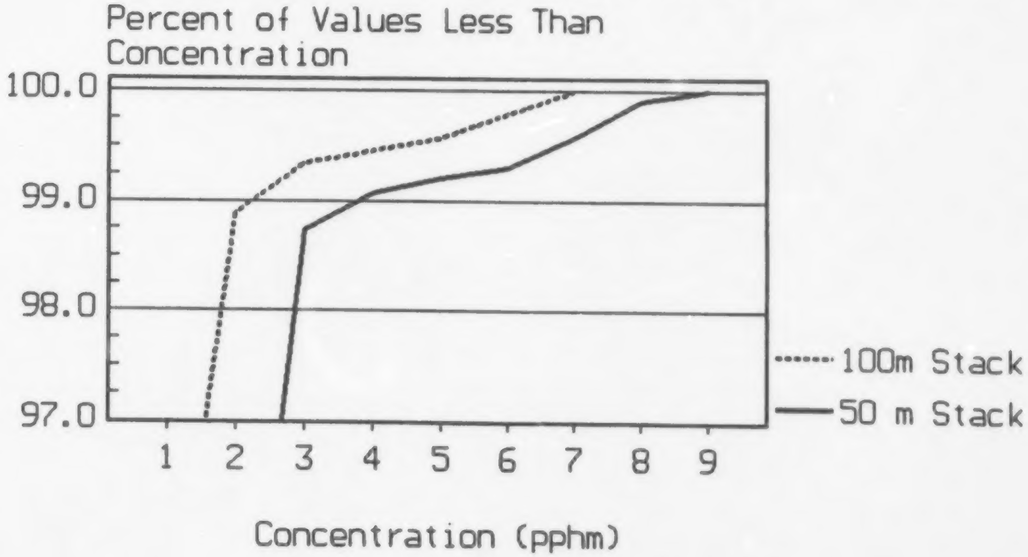


Fig. 6-9b

7.0 EXCAVATED MATERIALS CONSIDERATIONS

7.1 General

A relatively large volume of excavated material will result from the construction of the intake and distribution tunnels. In 1982, the Toronto Harbour Commission indicated that such material could be used to extend the Leslie Street spit. Since that time, the construction of the spit has progressed with materials from other sources and the attitude to lakefilling projects has changed. Also, new ideas for using the excavated material have been put forward.

This section summarizes the issues associated with the management of surplus excavated material in the Toronto area, updates previously proposed strategies and indicates further work required to verify the potential opportunities. The discussion is restricted to soil and rock resulting from the excavation of the main tunnels. No direct consideration has been given at this stage to excavations required for shafts and service connections.

Initially, the tunnel alignments and the characteristics of the materials requiring excavation are considered. Then, the potential excavated material use or disposal opportunities are identified and pertinent issues associated with each are presented. Finally, comments are made on the viability of the potential opportunities.

7.2 Subsurface Materials

7.2.1 Geology and Hydrogeology

A section showing geological units based on information collected during the construction of the Yonge Street subway is provided in Figure 7.1.

Sedimentary bedrock of the Georgian Bay formation is exposed in Lake Ontario and overlain by a complex series of Pleistocene deposits in the vicinity of and north of Toronto Harbour.

Thinly bedded shales, siltstones, mudstones and limestones are typically contained within the Georgian Bay formation. This formation was formed during the Ordovician age approximately 450 to 500 million years ago. The formation is estimated to be about 100 m thick and is underlain by the grey to block shales of the Collingwood formation.

Due to the scouring processes of recent glaciation, weathered shale has been stripped from the surface of this formation leaving sound shale present typically within about one metre of the bedrock surface. Weathered zones containing broken shale fragments and clayey shale may be encountered at greater depth within the shale bedrock in association with rubble zones which have been formed due to the relative movement of the bedrock along fractures or bedding planes.

The Pleistocene deposits consist of a combination of glacial and interglacial deposits. Detailed geological studies of these deposits have been carried out in the Don Valley brickyards. The oldest of the deposits is the York Till which was deposited on the shale bedrock during the Illinois glaciation. Later periods of glaciation resulted in the removal of much of this formation so that less than one metre of the York Till is typically present. A subsequent period of warm climatic conditions resulted in the deposits of up to 8 m of lacustrine clay and sands known as the Don formation or Don beds. Rising lake levels and the development of a cooler climate led to the deposition of the Scarborough formation which consists of clayey silt and sand units with occasional peat-rich layers. Wood fragments within this formation have been dated as more than 52,000 years old.

With the advance of the Wisconsin glacier, the Sunnybrook till was placed over the Scarborough beds. Stratified clay, silt and sand of the Thorncliffe formation were deposited over the

Sunnybrook till during a period of glacial retreat. The final Wisconsin glacial advance, approximately 27,000 years ago, led to the deposition of the Leaside Till which is the present surficial stratum in much of the Toronto area.

Following the retreat of the glaciers, the downtown Toronto area was inundated by Lake Iroquois. Leaside Till and the Thorncliffe formation clays and silts were eroded and Lake Iroquois silt and sand placed upon the Sunnybrook Till. Evidence of the Lake Iroquois shoreline may be observed in downtown Toronto near St. Clair Avenue and in particular at the site of Casa Loma.

South of Front Street, extensive man-made deposits (fill) and recent Lake Ontario beach and nearshore deposits (sand, silt) are found.

Groundwater levels near the waterfront generally reflect the level of Lake Ontario. Elsewhere, the water table slopes toward the lake and is generally believed to be within 10 m of the ground surface.

7.2.2 Shale Characteristics

Information on the shale was derived from the provincial publication RR229, Evaluation of Shales for Construction Projects. This publication indicates that the Georgian Bay Formation consists of two conformable units (formerly called Meaford and Dundas) having similar properties. These contain approximately 80% to 90% shale with interbedded limestone and occasional calcareous sandstone. The content of limestone and sandstone varies greatly with locality. General characteristics are as follows:

- colour is blue-grey to green-grey;
- thinly laminated;

- approximately 60% clay minerals (predominantly illite with some chlorite), 30% quartz, and 10% calcite, dolomite, and feldspar with occasional visible pyrite;
- glassy;
- commonly fossiliferous;
- medium strong (typically 30 MPa uniaxial compressive strength), brittle, and moderately fissile;
- durability ranges from low to very high
- typically thin to medium bedded and slabby with two sets of near-vertical orthogonal joints;
- weathering near the soil contact is accompanied by softening, increased fissility, and change to a pale grey colour

It is emphasized that this information is not necessarily accurate for all parts of the formation.

7.2.3 Soil Characteristics

As can be seen from Figure 7.1, the soils vary considerably. The Clay-rich Sunnybrook Till predominates but extensive sand and silt/clay units are also present.

Soil depths vary from approximately 5 m near the waterfront to approximately 40 m at Bloor Street.

7.3 Tunnelling Considerations

7.3.1 Vertical Alignment

The proposed alignment of the tunnel between the intake and the pumping station falls within the shale bedrock. However, the vertical alignments of the distribution tunnels have not yet been established.

South of Front Street, the soils include fill materials of unknown quality. In the vicinity of Front Street and for a considerable distance northward, the soils are quite shallow relative to the depth of existing buried facilities. Construction of the tunnels in this area in bedrock may be unavoidable. However, tunnelling in the soils north of Dundas Street may theoretically be possible. The advantages would be shallower shafts and service connections. Drawbacks may be the need to change the tunnelling technique and the discontinuity in the tunnel alignment. As well, the relatively high water table and the nature of the soils may not permit the use of cost-effective tunnelling techniques.

7.3.2 Tunnelling Method

The excavation would probably be carried out by means of a tunnel boring machine. Material from the intake tunnel excavation would be removed at a shaft at the waterfront and material from the distribution tunnel excavation would be removed at shafts constructed at 1,500 m to 3,000 m intervals. The rate of advance of the tunnelling machine in the bedrock would be of the order of 30 m in a 24-hour working day. Material would therefore be excavated at a rate of 25 m^3/hr. This is approximately equivalent to a generation rate of 60 tonnes per hour. The excavated material would require haulage to its intended destination.

7.4 Excavated Materials

7.4.1 Volumes

It has been estimated in Proctor & Redfern's report that approximately 250,000 m^3 of material would be excavated from the tunnels, 115,000 m^3 from the intake tunnels comprising shale and 135,000 m^3 from the distribution tunnels, probably comprising shale but possibly including some soil depending on the tunnel alignments selected. It should be noted that swelling and bulking of shale following excavation may increase the bulk volume by up to 100%.

7.4.2 Nature of Excavated Materials

The tunnel boring machine would tend to break away the fissile shale but would also grind the shale to some extent. The excavated material would therefore typically include large pieces with a maximum dimension of 150 mm (approximately 25%), sand-sized particles (approximately 25%) and a range of sizes in between.

7.4.3 Disposition Considerations

The following disposition constraints and opportunities have been identified:

- shale is not suitable for use as a concrete or asphalt aggregate
- the presence of interbedded limestone precludes the use of the shale as a raw material in the manufacture of bricks and for similar purposes
- the shale tends to disintegrate if exposed to the elements
- excavated shale has been used for fill purposes but generally must be broken up if settlement cannot be tolerated.

7.5 Disposition Options

The following potential disposition options have been identified:

- use as fill at a lakefill project such as the Leslie Street spit
- use as fill at a terrestrial development site such as Ataratiri
- use as cover material at or disposal at a private or municipal landfill

- use by the Ministry of Transport on future highway projects in embankment construction or for similar purposes

The issues associated with the disposition options are summarized below:

7.5.1 Lakefill Projects

There are costs associated with lakefilling excavated materials including haulage costs.

The main lakefill project in the vicinity of the proposed tunnels is the Leslie Street spit. It was recently estimated that the spit will be complete in 1993. However, since this projection was made, the fill rate has reduced considerably. Approximately 300 trucks a day are hauling fill materials to the spit at present compared to 1,000 trucks last year. However, even with the reduced fill rate, it is believed that the spit will be complete within five years.

Chemical testing of fill materials is required prior to acceptance of the materials at the spit. The requirements are set out in the Manual for an Improved Lakefill Quality Control Program. The Manual indicates that excavations of bedrock will not require chemical testing if the overburden is uncontaminated. If the overburden is contaminated to depth, shale may require chemical analysis. Excavated soil would require testing and may not meet the lakefill criteria in some areas. Shale from deep excavations in downtown Toronto has been accepted at the spit.

The Toronto Harbour Commission has no plans for further lakefill projects at this time. The whole issue of lakefilling has been examined by the Royal Commission on the Future of the Toronto Waterfront and will be addressed in a shoreline regeneration report scheduled for completion at the end of June 1991. It is expected that the report will advocate a cautious approach to lakefilling for ecological reasons. It is unlikely that lakefilling can be relied upon as a convenient means of disposing of surplus excavated soil in the future.

It should be noted that the Ministry of the Environment is intending to implement a new, comprehensive provincial lakefill policy. The new lakefilling guidelines may be more stringent than the current guidelines. At a meeting with provincial authorities on 17 January 1991, concerns were raised with respect to the use of the excavated material for waterfront land reclamation or lake dumping.

7.5.2 Terrestrial Fill

Most construction sites in downtown Toronto generate surplus excavated material. Historically, contaminated soils have been removed from former industrial sites undergoing redevelopment and replaced with clean fill. However, in response to high contaminated soil disposal costs, more effort is now being made to accommodate, by isolation or other means, contaminated soil at the site rather than removing it.

For example, the City of Toronto has developed a soil management plan for the proposed Ataratiri development project that results in a net surplus of excavated material, even though fill is required for flood protection and other purposes.

Chemical testing is required before excavated soil from former industrial sites can be used as fill. However, it is most unlikely that the excavated shale would fail these tests. It is possible that excavated soil could contain contaminants at concentrations of concern.

7.5.3 Landfill Sites

The Municipality of Metropolitan Toronto now charges a tipping fee of $150/tonne. As well, material bans have been implemented that would disallow acceptance of the excavated material at a municipal landfill.

Because of its heterogeneous nature, the shale would not be suitable for use as a landfill liner or cover. As well, its characteristics render it unsuitable for use as daily cover.

Private landfills may accept the excavated material at rates substantially less than the municipal tipping fee. However, the future availability of sufficient capacity at these landfills is questionable. They are also located a considerable distance from downtown Toronto.

7.5.4 Ministry of Transport Projects

A number of major highway projects in the neighbourhood of Metropolitan Toronto have been planned. Shale has been used by the Ministry of Transport in constructing road embankments. However, road alignments are generally designed to provide a reasonable cut and fill balance and imported fill is not usually required.

7.6 Summary

The excavation of the tunnels would generate a relatively large volume of excavated material including shale and possibly some soil. In general, the chemistry of the excavated materials is not likely to be a concern. The materials can be used as fill but cannot cost-effectively be used for other purposes.

It is not expected that there would be a strong demand for fill materials near downtown Toronto at the time of tunnel construction. However, as surplus excavated material will continue to be generated in the Toronto area for a number of years, disposal opportunities will undoubtedly develop in response to the demand. The fill sites may be some distance from Toronto and charges may be made by the site owners.

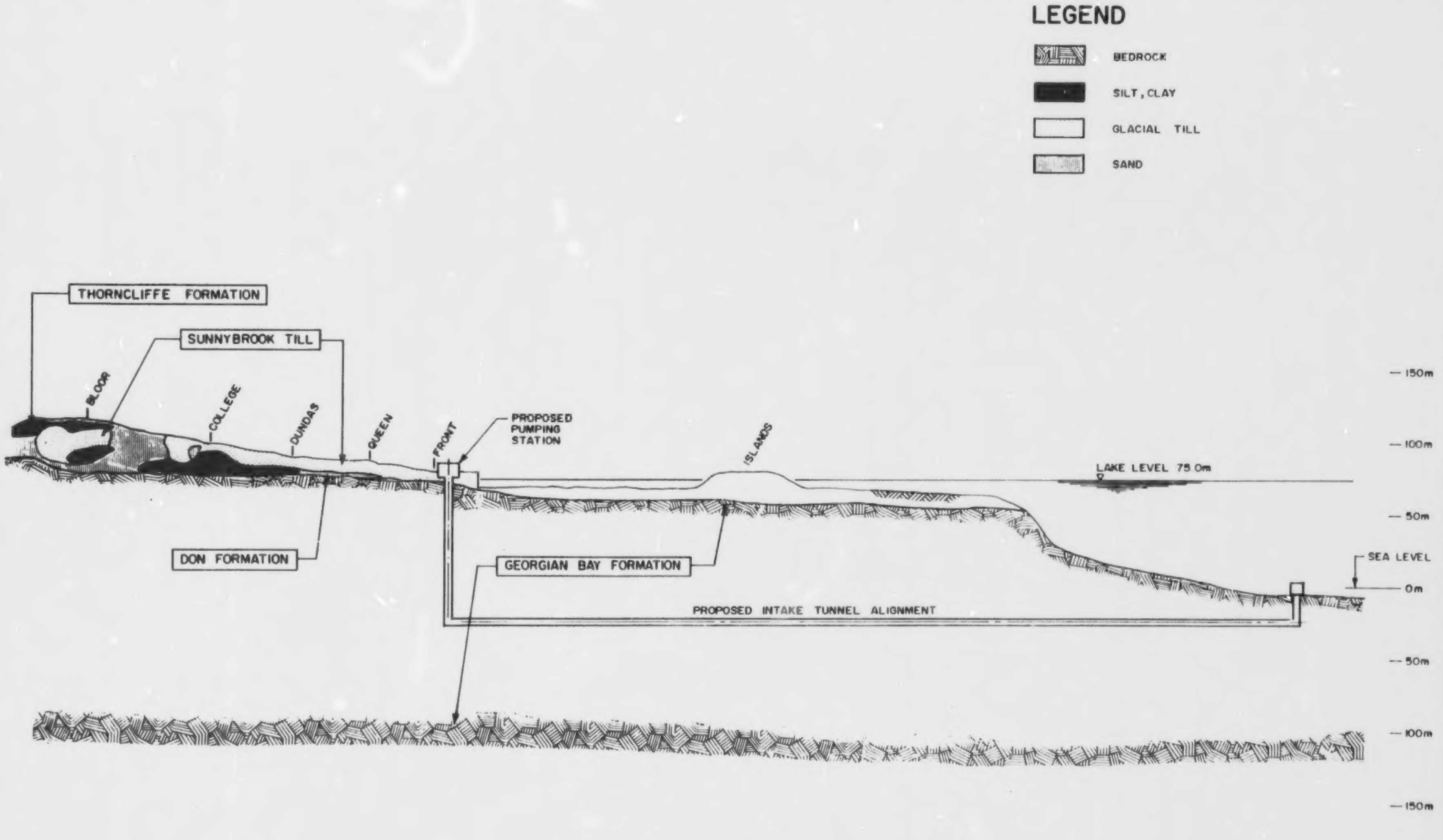

LEGEND
BEDROCK
SILT, CLAY
GLACIAL TILL
SAND
THORNCLIFFE FORMATION
SUNNYBROOK TILL
BLOOR
COLLEGE
DUNDAS
QUEEN
FRONT
PROPOSED PUMPING STATION
ISLANDS
LAKE LEVEL 75.0m
DON FORMATION
GEORGIAN BAY FORMATION
PROPOSED INTAKE TUNNEL ALIGNMENT
SEA LEVEL
150m
100m
50m
0m
50m
100m
150m

FIGURE 7-1
GEOLOGICAL SECTION

8.0 OTHER ISSUES

8.1 General

This section discusses briefly several issues that may have positive or negative impacts on the environment, or that have the potential to arouse the concern of interested parties, if the deep water cooling concept is pursued further.

8.2 Heat Rejection into Lake Ontario

The heat associated with the buildings served by deep water cooling will be transferred into the lake water via heat exchangers rather than into the atmosphere via evaporative cooling towers.

The significance of this effect on the lake water temperature, particularly in the Toronto Harbour area, has been reviewed in some detail in Section 3.0 of this report. However, to provide a further perspective on the significance of transferring this heat load from the air to the water system, we reviewed how the heat added to the lake by the deep water cooling concept compares with the heat rejected to the lake by Ontario Hydro's generation of electricity that otherwise would be required to operate conventional chillers in lieu of a deep water cooling system. This analysis showed that the amount of heat rejected into the lake would double.

To provide an additional perspective on the relative significance of the heat rejection to the lake compared with existing Ontario Hydro generation facilities, the following comparison is presented in Table 8.1.

The previous discussion provides some insight into the significance, or lack of significance, of the deep water cooling concept.

While the total heat release to the lake will be increased by the deep lake water cooling concept compared to the existing chiller evaporative tower systems, its impact can be expected to be less significance than the impact (if any) of one of Ontario Hydro power generation plant's cooling water system. A detailed review of the existing Ontario Hydro power station cooling water impacts on the lake water should be undertaken if deep lake water cooling proceeds to the next phase. Also, a review of historical records of temperatures experienced in the Niagara and St. Lawrence Rivers should be undertaken to establish whether any increases in water temperature after new hydro plants started up can be detected.

8.3 Heat Rejection into the Atmosphere

At the present time, heat extracted from buildings in the City's downtown area is released to the atmosphere, in most cases, by using evaporative cooling towers. Such units cascade recirculated cooling water from the chiller system down through the tower, while integral fans pass air upward, picking up moisture and carrying off the latent heat. This process utilizes evaporative cooling to efficiently extract the heat from the recirculated cooling water, releasing the heat load primarily by discharging moisture into the atmosphere. As a result, the wet bulb temperature and relative humidity of the exhaust air from the towers increases, although the dry bulb temperature changes very little. Calculations show the effect under maximum cooling load conditions could be expected to result in a dry bulb temperature reduction in the Toronto downtown area of less than 0.1°C, with a total moisture release of 2300 tonne of water per hour.

With implementation of deep water cooling, this heat release load will be eliminated, although at this stage, it appears a temperature change would not be detectable, over the entire area served by deep water cooling. Further review of the potential effect of elimination of the heat release to the atmosphere is presented in Section 6.0 of this report.

With implementation of deep water cooling, any localized nuisance problems associated with cooling towers will of course be eliminated. Such problems include the presence of visible moisture plumes during cooler weather periods, impingement of the vapour plume on surrounding building surfaces, possible noise nuisance due to operation of tower fans and cascading water flow, and localized effects on the comfort level of neighbours living in the area (i.e., as humidity rises in hot weather, heat release from the human body and from other evaporative cooling tower systems is reduced). Further review of localized evaporative cooling tower effects, including the potential releases of contaminants, is presented in papers prepared by the City of Toronto Health Department.

8.4 Surge/Water Hammer Considerations

Whenever long pipelines and/or high in pipe velocities are encountered in a large water distribution system, pressure surge or water hammer must be studied. Surge conditions occur if main line valves are closed too rapidly, if pumps shut down as a consequence of power failure, or if any other action occurs that causes the flow rate in the pipeline to be abruptly halted. When flow is stopped abruptly, the momentum of the water column within the pipeline causes a severe transient pressure to develop in the system. These pressure variations can be so significant that the pipe, system valve casings, or heat exchanger tubing could experience shear failure or burst. With a district cooling system, such conditions could result in significant property damage and/or personal injury.

Such problems are also common to potable water distribution systems, and with proper design, can be avoided.

At the present time, the effects of waterhammer on the deep water cooling concept have been reviewed on a preliminary basis in the Proctor and Redfern Report, although this review has been limited to the main north-south discharge tunnels leaving the pump house. Further analysis of this important aspect will have to be undertaken in subsequent phases. Special protection methods will be required to eliminate the risks for water hammer associated with both the intake tunnels and all of the cooling water supply and return distribution piping network.

8.5 Interested Parties Potential Concerns

8.5.1 General

In February and March, the Canadian Urban Institute met with various members of the Toronto community that have an interest in the deep lake water cooling concept. The purpose was to assess on a preliminary basis, the types of issues and concerns that may develop if it was determined that the project was economically and environmentally attractive. The following discusses those concerns that were identified during the consultation process and that have not been discussed previously in this report, or in reports prepared by others.

8.5.2 Approvals Requirements

As with most large projects, the major concern expressed related to the possibility that with Ontario Hydro and various levels of government participating in the development of the concept, and if the project receives positive support as a result of the Charrette, environmental approvals requirements may be compromised in order to implement the deep water cooling concept as soon as possible. Such concerns can be eliminated by the Minister of the Environment simply designating the project as having to be approved under the Environmental Assessment Act, independent of the type of proponent that is ultimately selected to implement the scheme. Alternatively, the proponent could volunteer to undertake a full environmental assessment by requesting the Minister to designate the project to come under the EA Act.

Reference is made to Section 2.0 of this report for an appreciation of the extent of the approvals that will be required under the Environmental Assessment, and other Acts having jurisdiction over such projects, before the deep water cooling concept can be implemented.

8.5.3 Potential for Lake Water Contamination

With the lake water being distributed through a district cooling system, with its extensive piping and heat exchanger systems, concern was expressed that leaded solder and other metal ions could be introduced into the circulating cooling water and therefore be discharged into the lake.

The deep lake water cooling system consists of a large 5 to 6 m diameter in rock intake, pumping units, large 2 to 3 m diameter in rock main north-south discharge and return water tunnels, relatively large, 100 to 760 mm diameter, east-west and building connection supply and return distribution piping systems, and individual building heat exchanger units. Considering the materials of construction that will be utilized for most, if not all, of the distribution system (rock cement mortar lined and welded steel piping), contamination is expected to be minimal and undetectable.

Since the pumping distribution piping system that will be required with the deep water cooling concept are similar to conventional potable water supply systems used in Metro, water quality test results on existing distribution piping systems could be reviewed to confirm contamination of the water by the piping systems is not a problem. If such test results are not available, they could be easily obtained if this aspect continues to be a source of concern. Most water supply quality tests are done at the end of the user's pipe, thus copper piping with soldered joints influence the results. Copper piping with leaded solder joints has been identified as a significant contaminant source in drinking water systems where a flow of water is tested after overnight zero flow conditions. Such results are not relevant to this concept because very little, if any, copper piping will be utilized.

A source of contamination that could potentially result with deep water cooling is entry of the building cooling system water into the deep lake water flow. This could occur if the heat exchangers used to extract the building heat from the building cooling system into the lake water developed a leak. In general, the building cooling system will be circulated at a higher pressure than the lake water side of the exchanger. The building coolant that could enter the lake water in the event of a heat exchanger leak could be contaminated with corrosion and/or algae inhibitors, or could be refrigerant. The significance of this contaminant potential should be reviewed further. The potential for leakage to become a problem could be minimized or eliminated by operating the building side of the heat exchangers at lower pressure than the lake water side, by frequent pressure testing of the heat exchanger for leaks, by utilizing an intermediate fresh water loop between the building and lake water pumping systems, or by avoiding the use of harmful additives in the building piping systems.

8.5.4 Sewage Plant Load Increases

A concern was expressed regarding the potential for the deep lake water cooling concept to add flow to Metro's already overloaded sewage plants. Since the distribution system is entirely separate from the City's water supply, storm and sanitary sewer systems, there would normally be no additional flow on the sewage plants if deep water cooling was implemented. The only condition that could result in water being discharged to the sanitary sewer system would be if an in-building heat exchanger or section of piping developed a leak. The leakage would be collected by the building floor drain system and enter the sanitary sewer. While this may happen, it would occur very infrequently, and would be of limited duration.

8.5.5 Alternate Water Supply Uses

With the extensive water distribution and pumping system associated with the deep lake water cooling concept, alternate uses of this water supply may be worth considering. The quality of the deep lake water is relatively high and free of zebra mussels. This makes its use ideal as a potential source of influent for new or existing drinking water treatment/supply plants, reducing or eliminating treatment costs; or for supply of commercial properties or municipal park lawn sprinkler systems. Such uses could be serviced during off-peak cooling demand periods (significantly lower demand every night during summer months), or by increasing the size of the deep water intake.

Further discussion of these aspects is contained in a report prepared by Metro Toronto Public Works Department.

Table 8.1

Heat Rejection into Lake Ontario Comparison

	Maximum Design Flow Rates (m^3/s)	Typical Temp. Difference of System (°C)	Maximum Flow Condition Megawatts	Normalized Rate (*)
Deep water cooling demand	37.9	8	22.3 Elect. 1200 Thermal	1.1
Darlington Nuclear Plant	150	13.1	3400 Elect. 8233 Thermal	0.67
Lakeview Coal Fired Plant	73	10.2	2400 Elect. 3120 Thermal	0.36
Lennox Coal Fired Plant	64	11.1	2000 Elect. 2975 Thermal	0.41
Pickering Nuclear Plant	226	11.0	4560 Elect. 10415 Thermal	0.63
- A	114	10.9	2160 Elect.	
- B	112	11.1	2400 Elect.	

(*) Normalized rate represents the lake water cooling flow rate that is required to displace (in the case of deep water cooling) or generate (in the case of Ontario Hydro) the power associated with the City's downtown building cooling load under maximum demand conditions. Units are Megawatts discharged into lake divided by Megawatts cooling provided.

22 Years Protecting
the Environment

POLLUTION PROBE

22 ans de protection
de l'environnement

May 21, 1991

Gillian Mason
The Canadian Urban Institute
2nd Floor, West Tower, City Hall
100 Queen Street West
Toronto, Ontario
M5H 2N1

Dear Gillian:

Please accept Pollution Probe's final report, An Examination of the Ecological Impacts of the Deep Lake Water Cooling System on Nearshore Ecosystems.

We were unable to fully explore possible mitigation measures to the ecological impacts of the system, however, we have included some in the report. We feel that it is too early to complete a comprehensive study of these measures because information about the project is still in very preliminary stages. As well, time and financial costs have proved additional constraints.

Possible uses for the fill also have not been included in this report. Some ideas that have been suggested include: using the fill to create reefs for fish habitat and spawning areas in the harbour, and using the fill in the proposed Ataratiri site if that proposal is approved. Regardless of its use, the fill should be tested for contamination, in particular, the fill dug from beneath the City.

Please contact us know if there are questions or points that require clarification. We have enjoyed working with you on this project and look forward to seeing you at the conference in June.

Sincerely,

Burkhard Mausberg
Researcher

Andrea Imada
Researcher

Pollution Probe • Probe Post 12 Madison Avenue, Toronto, Ontario M5R 2S1 (416)926-1907 FAX (416)926-1601

22 Years Protecting the Environment

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22 ans de protection de l'environnement

An Examination of the Ecological Impacts of the Deep Lake Water Cooling System On Nearshore Ecosystems

by

Burkhard Mausberg and Andrea Imada

Prepared for the

Deep Lake Water Cooling Investigation Group

Submitted to

The Canadian Urban Institute

May 1991

Pollution Probe • Probe Post 12 Madison Avenue, Toronto, Ontario M5R 2S1 (416)926-1907 FAX (416)926-1601

Acknowledgements

The authors would like to thank everyone who has given their time and effort in responding to our questions. In particular, we owe thanks to Paul Muldoon, Sarah Miller and Dr. Henry Regier.

DISCLAIMER

This study was undertaken by way of a contract between Pollution Probe and the Toronto District Heating Corporation. It is intended to be a survey of issues to be addressed.

Pollution Probe, at the submission of this report, has yet to formulate a policy on the Deep Lake Water Cooling proposal. As such, Pollution Probe neither opposes nor supports this proposal at this time.

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Table 5. Average Loadings of Selected Contaminants Carried by the Don River as Measured at Lakeshore Road (1987/88). 21

Executive Summary

This report examines the potential nearshore ecological impacts of the proposed Deep Lake Water Cooling (DLWC) system. Three possible outfall locations are considered: the Inner Toronto Harbour, the Don River and the offshore lake. The report also touches briefly on the potential ecological impacts of the intake pipe and comments on alternative options of using the DLWC outfall to "flush" sewers, supply ornamental water fountains, and recharge aquifers.

The writing of this report and the findings in this report do not, in any way, constitute Pollution Probe's support for the DLWC proposal. Apart from the nearshore ecological impacts of the proposal, Pollution Probe believes there are larger issues that require discussion and resolution before this project moves ahead.

The prediction of ecological impacts is limited by the preliminary nature of the information about the DLWC proposal. In particular, gaps in knowledge about outfall temperature and flow volume limited the degree of specificity in this analysis. In addition, time and financial considerations also played a role in limiting the amount of detail in this report.

Preliminary study shows that there are numerous potential nearshore ecological impacts of the DLWC outfall. In light of these findings, this report recommends that the Inner Toronto Harbour and the Don River should not be used as potential DLWC outfall sites. While the report does not examine extensively the potential ecological impacts of the offshore outfall, this location is likely to cause fewer environmental disturbances than the nearshore options. However, this requires further study.

Flow volume of the Inner Toronto Harbour would not be changed substantially, although the volume from the DLWC outfall will replace the harbour water approximately 4.5 times a year. The DLWC outfall will cause a considerable increase in the Don River flow rate, potentially resulting in erosion and increased sedimentation in the lower Don River and Toronto Harbour, and causing flooding problems.

Relative to the water temperatures of both the Inner Toronto Harbour and Don River, the temperature of the outfall would be higher in the winter and lower in the summer. Such changes will radically alter the temperature profile of the Inner Toronto Harbour and the Don River. The temperature changes will affect the physical characteristics, biological composition and water chemistry of the harbour.

Changes in flow volume and temperature could affect water flows in the Don River and the Inner Toronto Harbour and cause sediment resuspension. This would result in increased turbidity in the harbour or the river which, in turn, could have impacts on water quality and species habitat. The potential resuspension of sediments is extremely worrisome due to the high levels of toxic contamination in the harbour and the river.

The increased flow volume could potentially improve water quality in the harbour and the river by flushing out contaminated water into the open lake. However, lake currents flow to the west outside of the inner harbour, and this may contaminate water and sediments on the western beaches and disturb spawning areas in the lake.

The biota in the Inner Toronto Harbour and the Don River would undoubtedly be affected by the DLWC outfall. Changes in flow volume and temperature, the possibility of sediment resuspension, and changes in water quality will have an impact on habitat conditions and spawning areas, and affect species populations and diversity. The levels of impacts will be largely influenced by the outfall flow volume and temperature and their consequent effect on the characteristics of the thermal plume* and turbidity.

Locating the DLWC outfall offshore could also produce ecological impacts, which at this time, are difficult to assess due to the limited information available. Changes in localized offshore currents and water temperature can be expected which could affect habitat conditions and sediment distribution.

Finally, the DLWC proposal must be assessed in a broader ecological perspective and account for "ecosystem surprises" which encompass unanticipated ecological impacts on larger ecosystems which result from changes to small ecosystems.

Rigorous modelling and further assessment of many aspects of both the system and its potential ecological impacts should be conducted if the proposal is investigated further.

Regardless of the nearshore ecological impacts of the DLWC system, there are several issues that deserve serious deliberation in any future consideration of the proposal. Foremost, the environmental problems that have led to the DLWC proposal, most notably, energy inefficiency, have not been adequately addressed by developers, businesses or governments. Thus, the problem of energy inefficiency should be addressed prior to implementing the DLWC proposal.

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* Please note that, in this report, the term thermal plume refers to both colder and warmer DLWC discharges (relative to the ambient water temperatures).

Furthermore, if implemented, there are fears that the DLWC system will lead to an unacceptable adoption of a dilution approach to contaminant loadings and water quality problems. This report stresses that pollutants must be addressed at source.

There are also concerns that the proposed DLWC system could lead to expansion of the current system and proposals for new systems which will not receive the same critical assessment as the first system. Several DLWC systems could have cumulative detrimental effects on the Great Lakes ecology.

Other concerns include the potential infestation of zebra mussels in either the intake or outfall which could lead to the need for water treatment. Chemical water treatment in a DLWC system is ecologically unacceptable.

1. Introduction

1.1. The Concept

The Deep Lake Water Cooling (DLWC) system is a concept that would use deep lake water from Lake Ontario to cool buildings in downtown Toronto. The idea was put into practice on a small scale in the 1940's when lake water was used to cool the Eaton's department store and downtown theatres.[1] The viability of the concept was studied in 1981 by Engineering Interface Ltd. for the Canada Mortgage Housing Corporation, and further explored by the firm in 1984 for the Ministry of Energy.[2] In both cases, it appears that a lack of investors stalled further investigation of the proposal.

Engineering Interface Ltd. is currently undertaking a series of engineering and financing studies of the DLWC proposal. The current proposal involves pumping deep lake water through a six kilometre tunnel and underground pipes to heat exchangers which would cool downtown buildings.

At present, Engineering Interface estimates the total cost of the DLWC proposal to be almost three-quarters of a billion dollars. This amount includes taxes, legal fees, engineering, environmental engineering, and contingency costs. The total costs could be subsidized by Ontario Hydro under a program which provides financial incentives for electricity savings.

1.2. Purpose of this Study

Pollution Probe was contracted by the Toronto District Heating Corporation to study the potential impacts of DLWC on nearshore ecosystems. Specifically, this study examines the ecological impacts of three potential locations for the outfall: the Inner Toronto Harbour, the Don River and the offshore lake. The offshore location for the outfall is discussed only briefly due to time and financial restrictions. A brief analysis of the ecological impacts caused by the water intake was also requested.

This study does not examine all of the environmental impacts and implications of the DLWC proposal. As such, it is not a replacement for an environmental assessment. An environmental assessment would be a more comprehensive undertaking which would consider not only DLWC, but its alternatives. Furthermore, this study is limited by the degree of detail in the engineering specifications provided to Pollution Probe. A number of important parameters are not yet finalized, including:

(1) the seasonal variation of the cooling water requirements, showing exact water volume needs for each month;

(2) the seasonal variation in the temperature of the discharge;

(3) the number and locations of outfalls in the Don River scenario;

(4) the location and design of the Lake Ontario outfall; and

(5) the design of the water intake.

It is important to note that the information and figures provided to Pollution Probe are assumed to be correct. However, some may require further scrutiny.

The general unpredictability of ecosystems creates additional difficulties in assessing the entire range of environmental impacts on nearshore ecosystems.

Because of the information and time limitations, this report provides only a general analysis about the potential environmental effects of the proposed DLWC system, and does not preclude the possibility of further impacts.

1.3. Methodology

In making predictions about the possible environmental impacts of the outfall, a number of research methods were employed. Personal interviews were held with a variety of experts from the academic community, consulting firms and government. Scientific journals and numerous publications from the Ontario Ministry of the Environment and consulting groups were reviewed. Finally, Ontario Hydro reports and assessments about environmental impacts of its cooling water systems were also reviewed.

1.4. Overview of this Study

This report begins by briefly reviewing the engineering parameters which were used to predict the potential impacts on nearshore ecosystems. The potential ecological impacts are then reviewed for three outfall locations, the Inner Toronto Harbour, the Don River and offshore. A number of observations are also made for alternative scenarios, such as recharging aquifers or flushing storm sewers with the deep lake water. The report then identifies a number of ecological concerns with the water intake, and continues with a discussion of several larger issues associated with the DLWC proposal. A series of recommendations for the cooling proposal conclude this report.

2. Summary of the Engineering Design

The proposed DLWC system will service the area from the waterfront north to Bloor Street, between Jarvis Street to the east and Spadina Avenue to the west. Water would be drawn from Lake Ontario at a depth of 80 m at an initial temperature of 4 degrees Celsius. The discharged water would have an average temperature of 12.5 degrees Celsius, with a minimum of 9.5 degrees Celsius and a maximum of 14.5 degrees Celsius.[3] For the purposes of this report, Pollution Probe accepts these temperatures, but would like to note that they deserve closer scrutiny.

A draft report prepared by Engineering Interface Ltd. estimates that the DLWC system would require a maximum water volume of 38 m^3/s. The required volume will be seasonally variable, ranging from 38 m^3/s during July and August to 3.8 m^3/s during the winter. Engineers estimate that 135-million m^3 of deep lake water would be removed and warmed each year. According to a scientist from the Canada Centre for Inland Waters, this volume equals 0.1% of the total lake water at 4 degrees Celsius.[4]

Engineering Interface Ltd. recommends that the system be sized for 44 m^3/s to provide for over-capacity.[5] Furthermore, doubling the system capacity to 75.7 m^3/s has also been proposed based on estimates that cooling requirements will increase at 1.7% per year.[6]

The water intake tunnel would be approximately 6 km long, 4.27 m in diameter, and dug 15 m below the lake bottom.[7] The design specifications for the water intake have yet to be determined. Under the current proposal, water will be pumped by a station located on the waterfront and fed into supply pipes running below Yonge Street and University Avenue. Alternative streets for the pipes have also been considered in case Yonge Street and University Avenue prove technically impractical or economically unfeasible.

Three locations have been proposed for the outfall: the Don River, the Inner Toronto Harbour at the east end of the St. Lawrence Sugar parking lot, and some distance offshore into Lake Ontario. If placed in the Inner Toronto Harbour, the outfall box culvert would be 55 m long by 4.5 m high by 3.0 m wide.[8] Details for the other outflow designs are unavailable at this time.

A total of 32 megawatts (MW) will be required for pumping the water to the heat exchangers; however, energy recovery turbines near the outfall would recover approximately 9 MW.[9] Thus, the total electricity requirements for operating the DLWC system are estimated to be approximately 23 MW.

It is not anticipated that the water will need to be treated during the process.[10]

3. Ecological Impacts Resulting from Locating the Outfall in the Inner Toronto Harbour

This part of the report identifies the current conditions in the Inner Toronto Harbour and outlines the potential ecological impacts that could occur if a DLWC system were implemented.

3.1. Current Conditions

This section examines the current conditions, such as temperature, sediments, contaminants, flow and currents in the Toronto Harbour. This information forms the baseline data used to assess the potential nearshore ecological impacts of the DLWC outfall.

3.1.1. Water Flow and Volume

Figure 1, on the following page, shows the Toronto Harbour flow circulation. Water enters the harbour from the western gap and the Don River, and leaves the harbour through the eastern gap. The exchange of water in the inner harbour depends primarily on the following aspects:[11]

(1) the inflow and outflow through the eastern and western gaps;
(2) the inflow from the Don River;
(3) the inflow from the waterfront storm and combined sewer discharges; and
(4) direct precipitation and evaporation.

Currents outside the inner harbour generally flow from east to west, moving water towards the Western beaches.[12]

The estimated total volume of water in the Toronto Harbour ranges from a low of 28,126,000 m^3 to a maximum of 32,085,000 m^3.[13]

3.1.2. Water Quality

Figure 2 shows the temperature profile of the inner harbour as a function of depth and time of year. The temperatures were measured at the Ontario Ministry of Environment's (MOE) station 1364, which is located near the middle of the inner harbour.

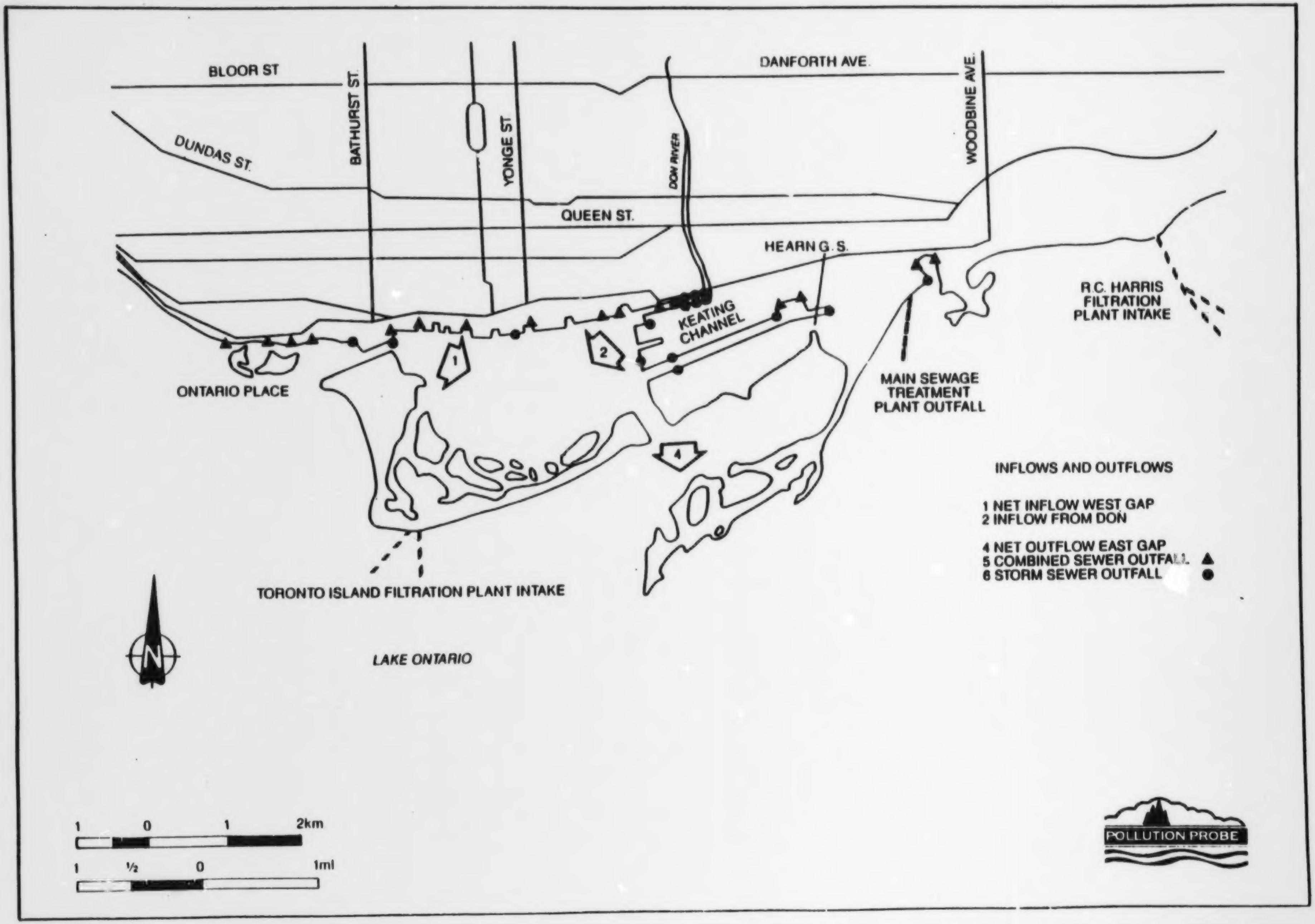
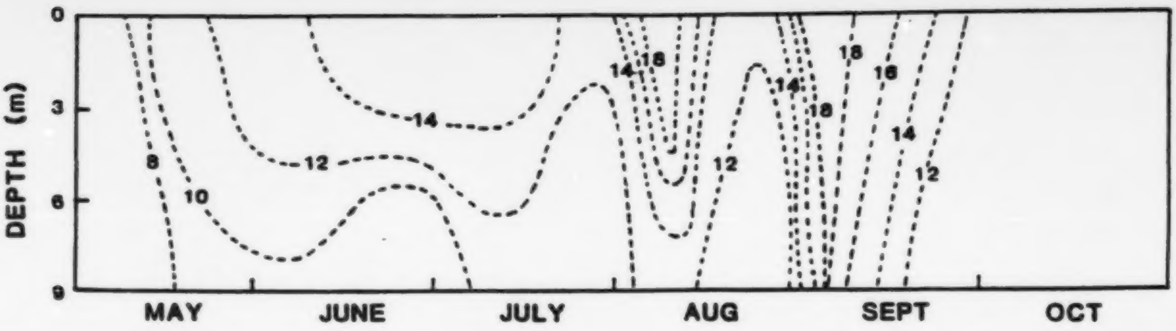

BLOOR ST
DANFORTH AVE.
DUNDAS ST.
BATHURST ST.
YONGE ST
DON RIVER
WOODBINE AVE.
QUEEN ST.
HEARN G.S.
KEATING CHANNEL
R.C. HARRIS FILTRATION PLANT INTAKE
ONTARIO PLACE
MAIN SEWAGE TREATMENT PLANT OUTFALL
1
2
4
TORONTO ISLAND FILTRATION PLANT INTAKE
LAKE ONTARIO
N
INFLOWS AND OUTFLOWS
1 NET INFLOW WEST GAP
2 INFLOW FROM DON
4 NET OUTFLOW EAST GAP
5 COMBINED SEWER OUTFALL ▲
6 STORM SEWER OUTFALL ●
1 0 1 2km
1 ½ 0 1ml
POLLUTION PROBE

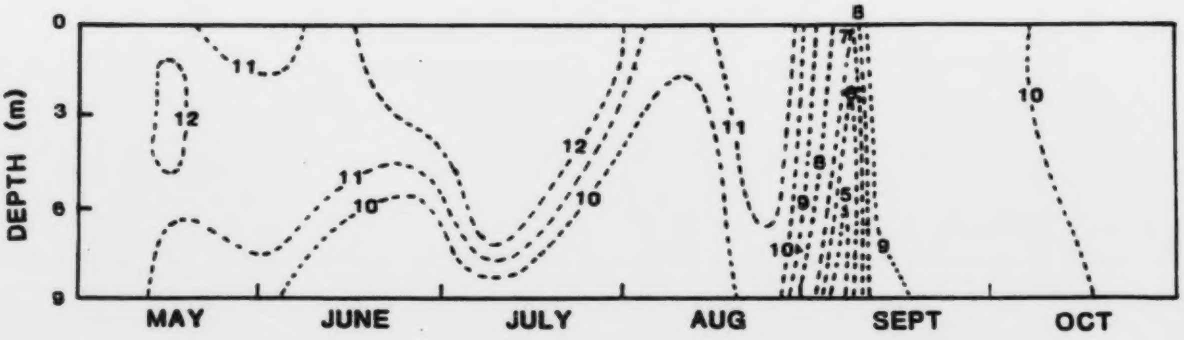
Figure 2. Temperature (degrees Celsius) of the Inner Toronto Harbour as a Function of Time and Depth.[15]



Currently, there appears to be little temperature stratification in the Inner Toronto Harbour during the months of November until May.[16] That is, little variation in water temperature as a function of depth occurs in the winter.

The dissolved oxygen content in the Inner Toronto Harbour, also measured at MOE's station 1364, is summarized in Figure 3.

Figure 3. Dissolved Oxygen Concentration (mg/L) in the Inner Toronto Harbour as a Function of Depth and Time.[17]



The water quality of the inner harbour is very poor. The Don River is major source of the contamination in the Toronto Harbour. For example, the Don is the source of 81 percent of the copper contamination, 90 percent of the lead contamination and 73 percent of the phosphorus loading into the harbour.[18] Storm and combined sewer outfalls are also significant sources of contamination in the harbour.

Although the concentration of total phosphorus in the harbour has declined significantly over the last 20 years, it still exceeds the MOE Provincial Water Quality Objective of 20 mg/l.[19] Table 1 lists the total phosphorous concentrations for three locations in the inner harbour.

Table 1. Total Phosphorous Concentration at Various Locations in the Inner Toronto Harbour.[20]

Location	Total Phosphorous Concentration (mg/l)
Keating Channel	139.3
Mouth of Keating Channel	80.5
Inner Harbour (Station 1364)	25.6

Levels of several metals such as cadmium, copper, lead, iron and zinc, as well as PCBs, dieldrin, lindane and DDT metabolites also frequently exceed the Provincial Water Quality Objectives.[21]

3.1.3. Sediments

After Hamilton Harbour, Toronto's inner harbour contains the most contaminated sediments in Ontario.[22] Inner Toronto Harbour sediments show greatly elevated levels of nutrients, metals, solvent extractables and PCBs.[23] The results of sediment sampling at MOE's station 1365 (near the middle of the inner harbour) and MOE guidelines are summarized in Table 2.

Table 2. Concentration of Various Contaminants in the Sediments of the Inner Toronto Harbour and Provincial Guidelines.[24]

Contaminant	Actual Concentration	Provincial Guidelines
Total Phosphorous	1.5 mg/g	1.0 mg/g
Total Organic Carbon	30 mg/g	10 mg/g
Copper	110 ug/g	25 ug/g
Chromium	120 ug/g	25 ug/g
Mercury	0.3 ug/g	0.3 ug/g
Iron	31 mg/g	10 mg/g
Zinc	380 ug/g	100 ug/g
Solvent Extractables	4.1 mg/g	1.5 mg/g

3.1.4. Biota

Despite the serious contamination of water and sediments, there are a number of species living in the inner harbour. For a detailed description of the existing species in the Inner Toronto Harbour, the reader is referred to the Metro Toronto Remedial Action Plan Stage 1 report.[25] Table 3 summarizes the important findings with respect to the biota found in the Inner Toronto Harbour.

Table 3. Summary of Biota Presently Found in the Inner Toronto Harbour.[26]

Type of Biota	Observations
Benthos	- reduced diversity; species present are typical of organically polluted areas.
Phyto-plankton	- biomass is higher and diversity is lower than in the offshore lake.
Zoo-plankton	- reduced diversity and abundance.
Fish	- diversity and abundance depends on season; on an annual basis.

3.2. Potential Ecological Impacts

This section identifies the potential ecological impacts of locating the DLWC outfall pipe in the Inner Toronto Harbour. Since many engineering parameters and their associated environmental confines are lacking at this point, predictions about ecological damage remain somewhat unspecific. Nonetheless, a number of projections can be made.

3.2.1. Impacts on Water Flow and Volume

There is little evidence that the flow regime of the inner harbour would be changed by the DLWC outfall; however, a modelling exercise will be necessary to confirm this.

Using an average harbour volume of 30,105,500 m^3, and a yearly average of 135,000,000 m^3 water used for DLWC, the water in the harbour will be replaced approximately 4.5 times a year due to the DLWC outfall.

The variability in the outfall volume and temperature is critical as it will affect the species habitat in the harbour (see section 3.2.4.).[27]

3.2.2. Impacts on Water Quality

Temperature

Assuming an average temperature of 12.5 degrees Celsius for the outfall water, the DLWC system will discharge colder water during the summer, while in the winter, DLWC will discharge warmer water (relative to the ambient temperature of the harbour water).

There is no doubt that this temperature shift will impact the physical characteristics, biological composition and water chemistry of the harbour. The precise impacts on water chemistry and physical characteristics are unknown at this point and need to be investigated further. However, a number of predictions can be made:

(1) due to the high discharge volume, the DLWC outfall will radically change the temperature profile of the inner harbour.[28]

(2) the increased temperature during the winter will increase the solubility of certain pollutants. For example, contaminants currently locked up in sediments may be liberated.

(3) during the summer, the colder water from the DLWC system will sink to the bottom and form underwater flows and streams.

(4) during the winter, ice formation may be inhibited by the discharge of warmer DLWC water.

(5) the change in water temperature may impact current efforts by the Ontario Ministry of Natural Resources to rehabilitate fish habitat.

Ontario Hydro has developed general models to estimate the vertical and horizontal dispersement of thermal discharges. To better determine the thermal dispersement of the water discharged by the DLWC process, a similar model could be developed.

Dissolved Oxygen

The dissolved oxygen content in the deep lake averages approximately 12.4 mg/l at a depth of 94 meters.[29] The dissolved oxygen content for the water in the inner harbour varies from 5 mg/l to 12 mg/l (see Figure 3, page 6).

The amount of dissolved oxygen in water depends on a variety of aspects, including the water temperature, the acidity of the water, and whether or not the water is in contact with air.

Oxygen concentration in water depends primarily on water temperature. The saturation concentration of oxygen at 5 degrees Celsius is 12.37 mg/l, and thus, the water at 94 m depth (12.4 mg/l) is fully oxygen saturated.[30] At 10 degrees Celsius, the saturation concentration decreases to 10.92 mg/l, while at 15 degrees Celsius the saturation concentration is 9.76 mg/l.[31]

Thus, based on saturation concentrations, it appears that a significant amount of O_2 will be lost due to the increase in water temperature. Since the harbour is already oxygen-starved, especially in the late summer months, the discharge of DLWC water will further degrade this parameter. Therefore, oxygen must be added to the DLWC water just prior to discharge. However, the feasibility and potential for success of adding O_2 needs to be further examined.

Total Phosphorous

An early question of the DLWC system related to the possibility that the cooling system may act as a nutrient pump. Such pumps move nutrients from nutrient-rich regions to nutrient-poor areas. Consequently, phosphorous concentrations in the deep lake were obtained and phosphorous loadings calculated.

On average, the total phosphorous concentration of water at 94 m depth is approximately 0.0128 mg/l.[32] This is lower than the current range of 25.6 mg/l to 139.3 mg/l for the inner harbour and 20 mg/l set as the Provincial Water Quality Objective. The expected average loadings of phosphorous from the DLWC into the inner harbour range from 4.7 kg/day (for an annual discharge of 135 million m^3) to 41.8 kg/day (for the maximum capacity of 1.2 billion m^3). While these loadings are at least ten times lower than average loadings from the Don River (448 kg/day), the impacts of additional phosphorous loadings into the harbour are unclear.[33] The water of the harbour will certainly become more eutrophic (nutrient-enriched).

Dissolved Nitrogen

As with dissolved oxygen, cold water contains higher levels of nitrogen than warm water. Since the DLWC system will warm the water, nitrogen super-saturation may occur, in which water can hold more nitrogen than normally possible. This phenomena can lead to nitrogen gas bubbles in the blood of fish. The extent to which nitrogen super-saturation may occur with the DLWC system is uncertain at this point and needs further investigation.

Contaminants

The DLWC system will act as a giant dilution mechanism; the relatively clean water from the deep lake will dilute the contaminants flowing into the harbour. Consequently, it can be anticipated that the water quality of the harbour will be improved and the Provincial Water Quality Objectives may be met for many contaminants. Again, a modelling exercise should be undertaken to predict the water chemistry based on current pollutant loadings and the increased water inflow into the harbour.

It should be noted that the solution to pollution is not dilution. If water quality improves in the harbour as a result of the DLWC outfall, it may lead to a false impression that the pollution problems of the harbour have been solved. This, of course, will not be the case, since contamination issues will only be solved if the problems are addressed at the source.

3.2.3. Impacts on Sediments

Since the sediments in the Inner Toronto Harbour are severely contaminated, the possible re-suspension and re-distribution of sediment contaminants by the DLWC outfall are worrisome. To this end, a number of possible ecological impacts may be observed, which include the following:

(1) if the flow velocity of the outfall is too fast, the sediments will be stirred up, thereby increasing the turbidity of the water and re-suspending contaminants into the water column. It appears, however, that the proposed engineering design reduces the flow velocity to below 1 ft/sec, which will disturb sediments only within 5 feet from the outfall.[34]

(2) the increased turnover of the water in the harbour may cause an increase in sediment removal from the harbour into the open lake. This may contaminate the western beaches since currents outside the harbour flow from east to west, or the sediments may settle on, and subsequently ruin, current

spawning areas in the open lake.

(3) the increased water volume entering the harbour will decrease the sediment trapping ability.[35] As a result, the amount of sedimentation in the harbour may decrease, while sedimentation outside the harbour, especially around the western beaches, may increase.

(4) during the summer, when the DLWC outfall is colder than the harbour water, rapid flowing, meandering cold water currents may form along the bottom, which may re-distribute and re-suspend sediments and its associated contaminants.

Overall, water quality is dependent on the quantity of suspended material in the water column as well as the quality of the suspended material itself. Therefore, in designing the DLWC system, attention must focus on limiting the quantity of suspended material. A mass balance model of sediment formation before and after DLWC may assist in predicting more precise impacts of DLWC outfall on sediments.

3.2.4. Impacts on Biota

By diluting the water in the Toronto Harbour, the DLWC discharge could potentially improve harbour water quality, consequently reducing the level of contaminant exposure to species. However, there are also potential negative impacts to species that must be examined.

Changes in water turbidity and the outfall plume resulting from the DLWC outfall are two factors which will likely have the most significant impact on species habitats and populations in the Inner Toronto Harbour. Flow volume and temperature of the outfall will affect the size, temperature, and stability of the outfall plume. The plume will be further influenced by wind, surface currents, and the weather.[36] Flow volume and velocity of the outfall are the major influences on sediment re-suspension and turbidity. The precise variability in the flow volume and temperature of the outfall must be determined before accurate assessments of the impacts on biota can be made. At this point, it is impossible to estimate these factors as they relate to the DLWC proposal. In addition, the ability of biota in the Toronto Harbour to adapt to different thermal habitats is a critical factor that requires further study.

While there are no similar projects against which to assess the potential impacts of the DLWC proposal on biota, some predictions can be made using the results of studies by Ontario Hydro about the ecological effects of thermal discharge from generating stations. Many studies have been carried out for

Ontario Hydro to study the biological impacts of once-through cooling systems.

The following potential ecological impacts were identified in Ontario Hydro studies and should be counted as impacts that could result from the DLWC proposal:[37]

(1) "effects on fish migratory activity, sexual maturation, egg incubation, incidence and severity of disease, and growth. Adverse influences on the timing and biomass of the planktonic, benthic and periphytic communities, the forage base for fish, were also foreseen."

(2) "the use of biocides and possible enhancement of eutrophying processes which could result in excessive development or undesirable blue-green algae."

Sediment re-suspension in the Toronto Harbour from the DLWC outfall could lead to a higher uptake of contaminants, which are now buried, by a variety of species. Consequently, these contaminants may bioaccumulate up the foodchain.

Another concern arising from the DLWC proposal is the displacement of aquatic organisms, such as plankton, from the deep lake into the nearshore habitat. If the plankton population and diversity in the deep lake water differs from that in the nearshore water, plankton populations and diversity in the Inner Toronto Harbour could be affected by the outfall. This may affect the ecosystem balance and the foodweb. A study of populations and diversity of plankton in the deep lake and nearshore ecosystems should be undertaken and the potential impacts of plankton displacement in the harbour assessed.

The following sections outline some additional impacts that could result from the DLWC system and summarizes findings about impacts on aquatic environments noted in studies undertaken for Ontario Hydro. Some impacts identified in some of these studies could not conclusively be attributed to cooling water discharges. Regardless, such impacts should still be considered as possible impacts of the DLWC system.

Plankton

In general, it has been difficult to assess accurately the effects of power generating stations on plankton. Nonetheless, some observations have been made and are worth repeating here.

(1) Phytoplankton. One study conducted at Pickering station showed "no statistically discernible effects" on inshore phytoplankton.[38] Another study which compared a control area to the combined discharges from Bruce and Douglas Point found few

differences in phytoplankton populations.[39]

(2) Zooplankton. One study concluded that changes in zooplankton populations have occurred around the Pickering station, however, it was not possible to attribute conclusively these variations to the operation of the plant.[40] The same study concluded that an extreme upper temperature of 35 degrees Celsius and rise in temperature of 12.5 degrees Celsius could cause a 20 percent rate of plankton mortality at the Pickering site.[41] As zooplankton living in the Toronto Harbour will not be exposed to these temperature extremes, mortality rates due to thermal changes will likely be less than 20 percent.

Periphyton

Studies conducted for Ontario Hydro show that periphyton (attached algae) are sensitive to temperature changes, with thermal discharges found to have seasonal effects on both populations and growing patterns.[42] The temperature change resulting from DLWC discharge could affect algae in the Inner Toronto Harbour, but more information about the DLWC discharge temperatures and flow volume variability are needed to properly assess these impacts.

Benthos

Studies assessing changes in benthic communities around power generating cooling systems have produced inconsistent results. Benthic populations and species diversity have increased around some stations, while decreasing at others.[43]

However, the studies did conclude that changes in benthic populations which can be attributed to thermal effects were observed only at shallow depths of 1 m within 1 km of the discharge location.[44] These findings are supported by a recent study which identified effects on benthic populations and distribution in the shallow waters around the Pickering station and attributed these effects to changes in thermal habitat.[45]

Benthic communities have been affected most rapidly when subject to substrate changes which occur on a seasonal basis.[46] Potential effects on the substrate of the harbour would have to be studied in detail to predict changes in benthic communities.

Fish

A study completed for Ontario Hydro in 1989 examined the impacts of thermal plumes on fish communities and identified several common patterns, which are summarized in the following excerpt:[47]

"(1) high variability of fish abundance within and among seasons, species and stations;

(2) no or few consistent differences in fish densities and species diversity between thermally impacted and control sites;

(3) decreased fish density with increased distance from shore;

(4) greater abundance of fish nearshore at night than day;

(5) greater abundance of fish nearshore associated with upwelling and storm events;

(6) orientation or clustering of fish near current or substrate structure associated with power plant operation and location as much or more than association with thermal structure."

Fish have a specific thermal habitat and can only live and reproduce in certain temperature ranges.[48] The introduction of cooler water during the summer and warmer water during the winter will attract some species and cause others to leave the harbour.[49] For example, studies undertaken by Ontario Hydro at three generating stations showed some re-distribution of nearshore fish communities according to temperature preferences of the species.[50]

Temperature variations will also affect fish egg survival rates. Laboratory experiments showed decreases in egg survival rates when eggs were subjected to a constant increase of over 3 degrees Celsius above simulated ambient temperatures. The tests showed significant decreases in survival rates when eggs were exposed to temperature increases immediately following fertilization and during hatching.[51] An example of the thermal sensitivity of fish eggs is provided in an Ontario Hydro report which found that temperature increases of 1 degree Celsius on the lake bottom could disrupt the hatching of whitefish.[52]

Analyses of the thermal sensitivities, preferences and tolerance limits of fish species in the Inner Toronto Harbour could be carried out to determine the potential impacts of the DLWC discharge on habitat, spawning and egg survival. These findings should then be compared with the anticipated characteristics of DLWC thermal plumes to more accurately assess the potential impacts on fish species.

One final note with regards to fish: under the federal Fisheries Act, anyone destroying fish habitat must create an equal amount of fish habitat prior to destroying the original habitat. That is, a net loss of fisheries habitat is not permitted under federal law. Thus, the proponent of the DLWC system will need to determine the exact amount of fish habitat which will be destroyed.

Waterfowl

It is difficult to conclusively assess the impacts of thermal discharge on waterfowl. A study conducted around the Pickering generating station reported a decrease in the species count, however, the study could not conclusively attribute the decline to the presence of the thermal plume.[53]

Ontario Hydro's Sampling Plan

Appendix A shows an environmental studies sampling plan used by Ontario Hydro in assessing biota changes and effects due to the impacts of the Darlington nuclear power generating station. Designing and implementing a similar sampling plan may be necessary for the DLWC project.

Zebra Mussels

Although the DLWC outflow will be 0.5 ft/sec, zebra mussels may still pose problems, especially during the low winter flows. The mussels could infest the pipe and block its discharge. The DLWC proponent should be absolutely certain that zebra mussels cannot enter or block the discharge pipe.

3.2.5. Ecosystem Integrity and Surprise

Lake Ontario is part of the Great Lakes ecosystem, and thus, the DLWC proposal must be assessed from a broader, ecosystematic view. A complete environmental assessment must examine how the proposal would enhance or degrade ecosystem integrity, and the possibility that the Great Lakes ecosystem could respond with a "surprise" reaction. Several Great Lakes experts believe that the integrity of the Great Lakes will be degraded as a result of the DLWC system.[54]

The notion of ecosystem surprise relates to unforeseen events and phenomena such as ecological impacts on large systems prompted by changes to smaller systems. In effect, it is difficult to predict events for a large system by predicting events of only a small subsystem.[55] In the case of DLWC, it means that ecological impacts may be predicted for the inner harbour, but ecological surprises for the Great Lakes ecosystem can be expected.

In the Great Lakes basin, most surprises are unwelcome because they cause harm to humans and other species, and their ecosystematic influence is generally disintegrative, at times to a disastrous extent.[56] With respect to unpleasant surprises that accompany ecosystematic disintegration, a policy of anticipate-and-prevent should focus on anticipating and preventing harmful cultural practices before they are instituted and affect the environment.[57] Many natural ecosystematic surprises, or the effects of cultural activities as mediated by the natural system, will not be anticipated even under rigorous scrutiny.[58]

4. Ecological Impacts Resulting from Locating the Outfall into the Don River

One alternative scenario would see the DLWC outfall located in the Don River. This part of the report identifies the current conditions in the Don River and outlines the potential ecological impacts that could occur if a DLWC system were implemented.

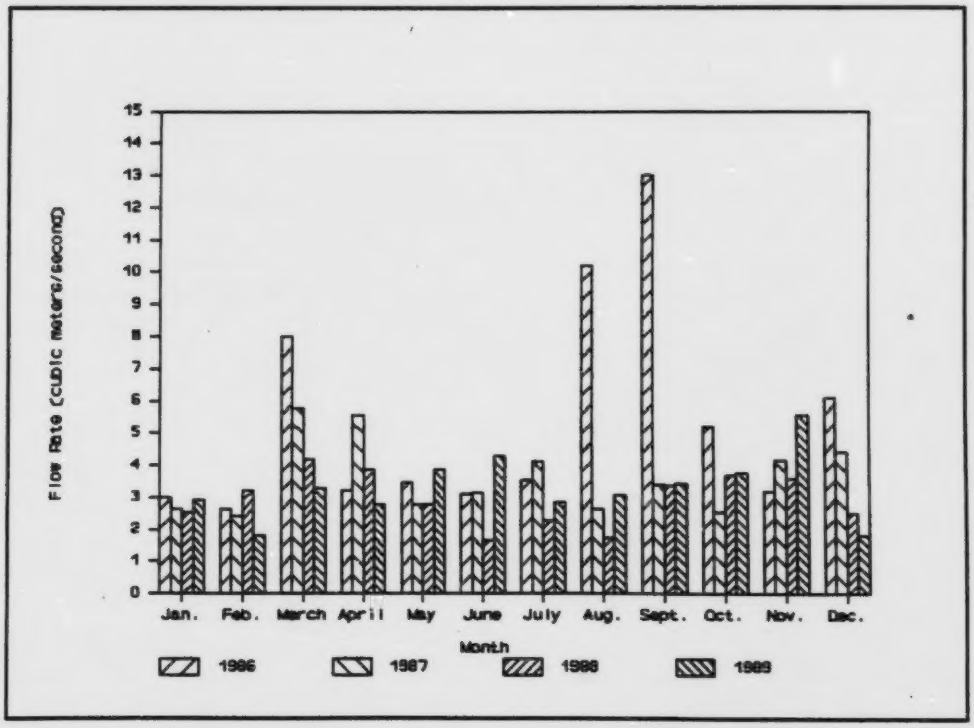
4.1. Current Conditions

This section examines the current conditions, such as temperature, sediments, contaminants, flow and currents in the Don River. This information forms the baseline data used to assess the potential nearshore ecological impacts of the DLWC outfall.

4.1.1. Water Flow and Volume

Figure 4 shows the average monthly flow rates for the Don River from 1986 to 1989.

Figure 4. Average Monthly Flow Rates for the Don River, 1986-1989, measured at Todmorden Mills.[59]



The maximum flow rates for each of the sampled years are summarized in Table 4, reflecting severe rain storms which temporarily increase the river's flow rates. These events flush out contaminants, while moderate regular flows do not do so.

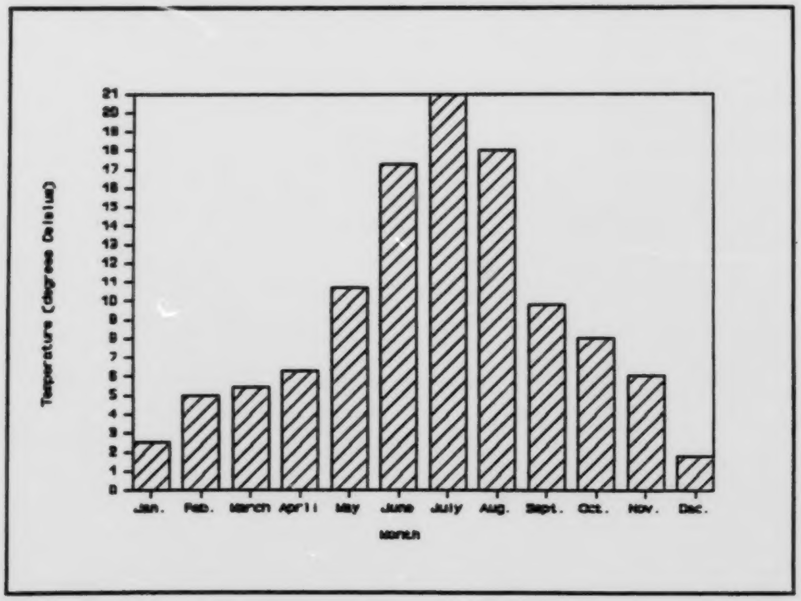
Table 4. Maximum Flow Rates for the Don River, 1986-1989, measured at Todmorden Mills.[60]

Year	Date	Flow Rate (cubic meters/second)
1986	September 11	85.6
1987	March 1	24.4
1988	September 4	23.3
1989	September 22	17.9

4.1.2. Water Quality

The water temperature of the Don River varies seasonally from 1 degree Celsius in January to 22 degrees Celsius in August. Figure 5. summarizes the annual variation in water temperature.

Figure 5. Annual Variation in Water Temperature of the Don River, Measured at Lakeshore Road (1990).[61]



The dissolved oxygen content and the total phosphorous concentration in the waters of the Don River also vary with season (see Figures 6 and 7).

Figure 6. Annual Variation in Dissolved Oxygen in Don River Water, Measured at Lakeshore Road (1990).[62]

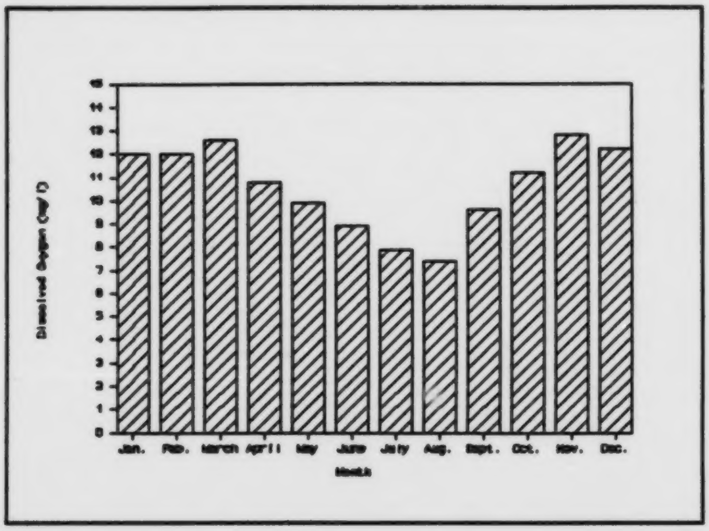
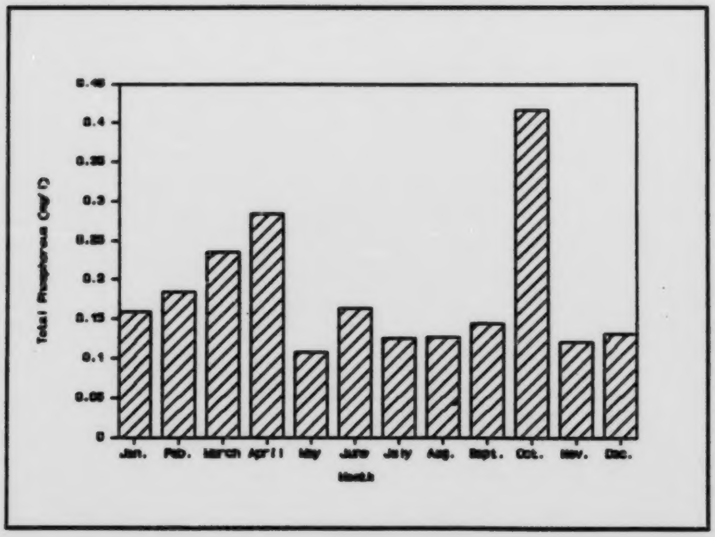


Figure 7. Annual Variation in Total Phosphorous Concentration in Don River Water, measured at Lakeshore Road (1990).[63]



There is little doubt that the Don River has been seriously contaminated for over 20 years. The concentration of pollutants are lowest in the upper Don River and increase downstream. A recent study calculated the pollutant loadings carried in the Don River before it empties into the Inner Toronto Harbour. These loadings are summarized in Table 5.

Table 5. Average Loadings of Selected Contaminants Carried by the Don River as Measured at Lakeshore Road (1987/88).[64]

Contaminant	Loadings (kg/day)
Ammonia	189
Nitrate	630
Total Phosphorous	448
Chemical Oxygen Demand	8,020
Dissolved Organic Carbon	1,622
Chromium	18
Copper	13
Iron	747
Nickel	144
Lead	7
Zinc	23
Mercury	39

4.1.3. Sediments

The sediments of the Don River are also seriously contaminated. At a number of locations, the sediments have a "greasy, oily texture".[65] The sediments in the Keating Channel have been sampled extensively and found to show elevated levels of phosphorous, chromium, copper, lead, zinc, iron, PCBs and solvent extractables.[66] The concentration of contaminants in the Keating Channel sediments was generally lower than that of the Inner Toronto Harbour.[67]

4.1.4. Biota

For a detailed biological inventory of the Don River, see the report prepared for the Ministry of the Environment.[68] For the purposes of this study, the two major findings of this report are summarized below:[69]

(1) 23 species of fish were found in the Don, the four most common, which are tolerant of pollution, were (in order of decreasing frequency): creek chub, blacknose dace, white sucker and longnose dace; and

(2) the benthic community shows a substantial number of pollution tolerant species.

4.2. Potential Ecological Impacts

It should be emphasized that the predictions of ecological impacts on the Don River by the DLWC system are severely limited because of the uncertainties as to where any outfall would be located. In addition, the exact seasonal variability in the water volume and outfall temperature remains unknown. Thus, in discussing the impacts, a discharge rate of 38 m^3/s from a single outfall has been assumed.

It is understood that this may be an unreasonable assumption, however, for the purposes of this report a worst-case scenario is being adopted. Having two outfalls, one located in the Don, with a flow of 5 m^3/sec, and the other one located in the harbour or offshore lake, may be a way to avoid the significant impacts on the Don created by the large discharge volume.

4.2.1. Impact on Water Flow and Volume

The flow regime of the Don River would be significantly affected by the discharge of the DLWC water. The likely impacts include the following:

(1) the maximum average monthly flow rate of the Don is less than 6 m^3/s, and thus, discharging 38 m^3/s (at capacity) would increase the flow rate six-fold.

(2) the additional water is likely to cause erosion and increase sedimentation in the River and Lake Ontario. Consequently, additional dredging would be required in the Keating Channel and Inner Toronto Harbour.

(3) the Lower Don River has a very low gradient and is prone to flooding. Thus, the additional water may cause an increase in flooding.

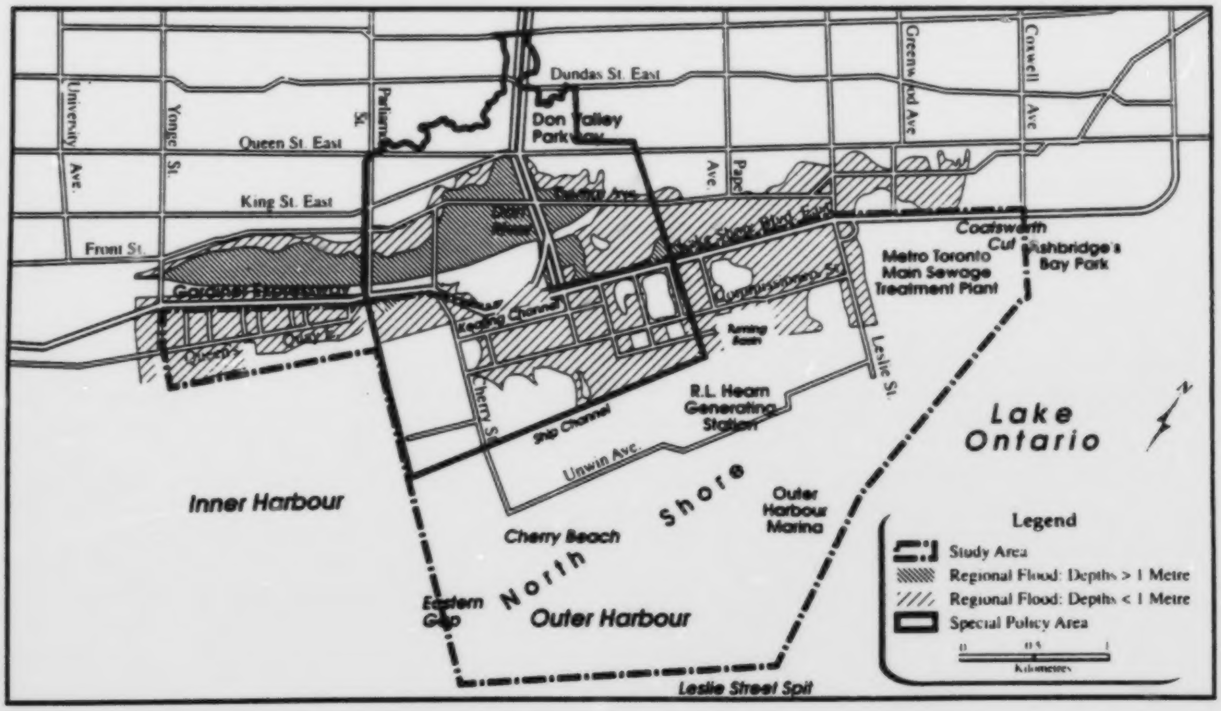
(4) additional channeling will likely be necessary, disrupting and eliminating habitat space.

(5) the increased water volume may cause problems at the 90 degree turn of the Keating Channel.

It remains unknown how the seasonal variability of the discharge of DLWC water may impact the Don's flow regime. Thus, a modelling exercise of the Don's altered flow regime may prove to be quite useful.

With regards to flooding problems, Figure 8 shows the area of flood potential in the Don Watershed. In August 1989, the ministries of Natural Resources and Municipal Affairs, and the Metropolitan Toronto and Region Conservation Authority approved in principle an application by the City of Toronto for a special policy area in the Lower Don floodplain. This special policy area is indicated in Figure 8, and the DLWC proponent must consider this policy area if plans are made to discharge DLWC water into the Don.

Figure 8. Potential Flood Conditions and Special Policy Area.[70]


Dundas St. East
Don Valley Parkway
University Ave.
Yonge St.
Parliament St.
Queen St. East
King St. East
Front St.
Gardiner Expressway
Keating Channel
Greenwood Ave
Coxwell Ave
Pape Ave.
Coatsworth Cut
Ashbridge's Bay Park
Metro Toronto Main Sewage Treatment Plant
Turning Basin
Leslie St.
Cherry St.
Ship Channel
R.L. Hearn Generating Station
Unwin Ave.
Lake Ontario
N
Inner Harbour
North Shore
Outer Harbour Marina
Cherry Beach
Eastern Gap
Outer Harbour
Leslie Street Spit
Legend
Study Area
Regional Flood: Depths > 1 Metre
Regional Flood: Depths < 1 Metre
Special Policy Area
0
0.5
1
Kilometres

4.2.2. Impacts on Water Quality

Temperature

Assuming an average temperature of 12.5 degrees Celsius for the discharged water, the DLWC proposal would discharge cooler water from May to October and warmer water from November to April.

There is no doubt that this temperature shift will impact the physical characteristics, biological composition and water chemistry of the Don River. The precise impacts on water chemistry and physical characteristics are unknown at this point and need to be investigated further. However, a number of possible predictions can be made:

(1) the temperature regime of the Don will be significantly altered.

(2) the increased temperature during the winter will increase the solubility of certain pollutants.

(3) during the winter, ice formation may be inhibited by the discharge of warmer DLWC water.

(4) the Don River experiences flooding problems in the winter due to ice build up in the Keating Channel.[71] The warmer DLWC water in the winter may alleviate flood problems by melting the ice or by preventing ice formation.

Again, using Ontario Hydro models which predict the thermal water dispersement may be useful for the DLWC system.

Dissolved Oxygen

The dissolved oxygen content in the Don River water varies from 7.4 mg/l in August to 12.8 mg/l in November (see Figure 6, page 20). The dissolved oxygen content in the deep lake averages approximately 12.4 mg/l at a depth of 94 meters.

Oxygen concentration in water depends primarily on water temperature. The saturation concentration of oxygen at 5 degrees Celsius is 12.37 mg/l, and thus, the water at 94 m depth (12.4 mg/l) is fully oxygen saturated.[72] At 15 degrees Celsius, the saturation concentration decreases to 9.76 mg/l, while at 10 degrees Celsius the saturation concentration is 10.92 mg/l.[73]

Thus, based on saturation concentrations, it appears that a significant amount of O_2 will be lost due to the increase in water temperature. Since the Don is already oxygen-starved, especially in the late summer months, the discharge of DLWC water will further degrade this parameter. Therefore, oxygen must be added to the DLWC water just prior to discharge. However, the feasibility and potential for success of adding O_2 needs to be further examined.

Dissolved Nitrogen

As with dissolved oxygen, cold water contains higher levels of nitrogen than warm water. Since the DLWC system will warm the water, nitrogen super-saturation may occur, in which water can hold more nitrogen than normally possible. This phenomena can lead to nitrogen gas bubbles in the blood of fish. The extent to which nitrogen super-saturation may occur with the DLWC system is uncertain at this point and needs further investigation.

Total Phosphorous

On average, the total phosphorous concentration of water at 94 m depth is approximately 0.0128 mg/l. With several exceptions (see Figure 7, page 20), the water of the Don River has a higher phosphorous concentration than 0.0128 mg/l.

The expected average loadings of phosphorous from DLWC range from 4.7 kg/day (for an annual discharge of 135 million m^3) to 41.8 kg/day (for the maximum capacity of 1.2 billion m^3). At the mouth of the Don River, the total phosphorous loadings are 448 kg/day, and thus, the DLWC project appears to add an insignificant amount of phosphorous into the Don.

Contamination

The water from the DLWC project would act as a giant dilution factor; the relatively clean water from the deep lake will dilute the contaminants present in the Don River. Consequently, while the Don may carry similar pollutant loadings, it is anticipated that water quality of the Don could be improved and Provincial Water Quality Objectives may be met for certain contaminants. Again, a modelling exercise should be undertaken to predict the water chemistry based on current pollutant loadings and the increased water inflow into the Don.

It is important to note that flushing the Don River with huge amounts of water is not an appropriate solution to "cleaning up" the Don. Indeed, the DLWC system may lead to a false impression that the pollution problems of the Don are solved. The pollutant loadings into the Don will remain unacceptably high, and such contamination must be addressed at the source. There are fears that DLWC may act as a disincentive in addressing toxic and conventional pollutants at the source.

4.2.3. Impacts on Sediments

Since the sediments in the Don River are severely contaminated, the possible re-suspension and re-distribution of sediment contamination by the DLWC outfall must be considered. To this end, a number of possible ecological impacts may be observed, including:

(1) the increased water volume may sweep out the sediments in the Don River. This may contaminate the Inner Toronto Harbour, the open lake, or the Western Beaches. The flushed-out sediments may also settle on spawning areas, thereby ruining them.

(2) contaminants currently locked-up in the sediments will be released.

(3) the increased water volume entering the Don may decrease the sediment trapping ability.

(4) erosion and sediment re-suspension could increase the turbidity of the Don.

Overall, water quality is more dependent on the quantity of suspended material in the water column than the quality of the suspended material itself.[74] Therefore, in designing the DLWC system, attention must focus on limiting the quantity of suspended material due to erosion. A mass balance model of sediment formation before and after DLWC may be an appropriate course of action to assess impacts to sediments more accurately.

4.2.4. Impacts on Biota

The impacts on biota in the Don River will be similar to the ones described in section 3.2.4. of this report. In addition, the following effects and considerations must be appraised:

(1) the location of the outfall pipe should be fairly high upstream if the fisheries are to be revitalized with the DLWC outflow.

(2) the faster flow of the river may displace some species currently living in the Don.

(3) variations in flow volume of the DLWC discharge could cause seasonal impacts, such as reduced spawning. Moreover, once the water flows into the Don, shutting off the supply could

again affect habitat conditions and have an impact on species which cannot adjust to continually changing habitats.

4.2.5. Ecosystem Integrity and Surprise

Please see section 3.2.5. which also applies for discharging DLWC water into the Don River.

5. Ecological Impacts Resulting from Locating the Outfall in the Offshore Lake

Due to time and financial limitations, the ecological impacts of locating the outfall in the offshore lake have not been extensively researched.

As in the analyses of the other outfall locations, the absence of information about flow volume and temperature of the DLWC discharge limits the analysis of the potential ecological impacts. In addition, the engineering parameters are very unclear for this option. Basic information that has not been determined includes: the design of the outfall; the location of the outfall (relative to the shoreline); and the depth of the outfall (relative to the depth of the Lake). The ecological impacts of locating the outfall offshore can be better assessed when there is greater certainty about these parameters.

Studies assessing the impacts of outfalls from power generating stations and municipal sewage treatment plants could lend relevant insight to an analysis of the potential ecological impacts of the DLWC outfall.

Nonetheless, a number of observations can be made:

(1) Thermal plumes from the DLWC discharge will affect offshore currents and water temperature, and have a consequent effect on current habitat conditions. There is a need for further study in related areas, including:

  (a) the ecological implications of locating the outfall at different lake depths;

  (b) the movement and mixing of thermal plumes in offshore water currents and flows;

  (c) a study of biota which reside offshore and their thermal tolerances and preferences; and

  (d) the potential impacts of the thermal plume on biota.

(2) Sediments may be stirred-up and distributed elsewhere in the lake.

(3) Zebra mussels could pose problems for an outfall located offshore if at any time no water flows out.

(4) In addition to the ecological impacts of operating the DLWC system, the impacts arising from the construction of the outfall must be taken into account. Such impacts could include destruction of habitat and spawning grounds.

To assist in developing and modelling outfall designs, Ontario Hydro has developed a Hydraulic Model Laboratory. The same or a similar model could be used to assist in the assessment of DLWC outfall designs.

Several experts have suggested that locating the discharge pipe into the lake may have the least ecological effects.[75] This is primarily due to the larger dispersal capability of the lake as compared to the Don River or the Inner Toronto Harbour. Furthermore, the contaminated sediments in the Don and harbour will not be re-suspended and distributed (the sediments in the offshore lake are less contaminated).

6. Comments About Alternative Scenarios of Dealing with DLWC Water

6.1. Flushing the Storm Sewers

Using the outfall to flush sewers is a questionable option and should be avoided. Underlying this option is the assumption that flushing the sewers will clean them of contamination. However, this dilution approach to pollution clean-up is unacceptable since pollution must be addressed at the source. Furthermore, Toronto has an ancient sewage system which is in urgent need of upgrading. Metro Toronto has been identified as an official Area of Concern by the International Joint Commission, and one reason for this classification is the poor state of the sewage system. If spent water is to be discharged into sewers, the maintenance and operational costs of the sewage system will increase. In addition, using the sewer system for discharge could produce operating subsidies for DLWC user. It is possible that some of the DLWC system costs will be absorbed by the public who pays for an already underpriced sewage system.

Also, retention facilities for storm water are increasingly being constructed to retain the storm water and then treat it in the main sewage treatment plant. Additional water from the DLWC system will overflow such retention tanks and may cause an unnecessary need to expand them.

It has been proposed that the storm sewers would be used as a DLWC discharge receptor only during dry weather. This scenario also raises several questions including which alternative outfall options would be employed when it rains.

6.2. Water Fountains

While the idea of having more water fountains in the City may be an attractive one, the use of the sewage system as the disposal for fountain water is unacceptable for the same reasons as outlined above. In addition, the water temperature may be further altered while circulating in the fountains, but more information is necessary to confirm this.

6.3. Recharging Aquifers

Not enough information is available to comment in detail on this discharge alternative. For example, there is no information about which aquifers would be recharged, and at what rate and how they would be recharged. Nevertheless, some comments can be made.

By using DLWC water to recharge aquifers, the use of DLWC water changes fundamentally. Instead of being a coolant that is returned to the source, DLWC water is now being consumed and taken away from the lake. In addition, there are many uncertainties in the scientific community about the potential ecological impacts of recharging aquifers. A thorough separate assessment is required before this alternative should even be considered.

7. Potential Ecological Impacts Caused by the Intake

This section briefly examines some factors that should be considered when designing the DLWC intake. At this time, the precise design of the intake is uncertain and it is impossible to conduct a comprehensive analysis of its potential impacts. In addition to the limited technical information, the short time-frame for this report has made it difficult to accurately determine which species thrive in the deep lake.

Given these limitations, this section is not intended as a comprehensive analysis of all the potential impacts associated with the DLWC intake. Rather, it identifies the major factors that have been considered in the design of other water intake systems.

There are four factors that must be examined when designing and placing the DLWC water intake. An Ontario Hydro study identified the "entrapment of organisms in the cooling water flow and their subsequent destruction as a result of impingement on screening systems or entrainment in the condensers" as potential impacts of once-through cooling systems.[76] Water drawdown and system operations are additional concerns that should be addressed.

7.1. Entrapment

The DLWC intake should be designed to avoid entrapping fish in the tunnel. A report undertaken for Ontario Hydro found numerous factors affecting entrapment including, "generating station design, operation, fish behaviourial responses and environmental conditions."[77] The report also noted that "large quantities of fish, principally schooling species... are entrapped at existing cooling water intakes" and that species entrapment varied with location of the intake and season.[78] These factors, along with the species populations in deep lake water, will have to be considered in designing and placing the DLWC intake.

Zebra mussels have already caused numerous and, as yet unsolved, problems for water intake systems in the Great Lakes. Current studies indicate that zebra mussels do not settle in temperatures of 4 degrees Celsius.[79] However, the possibility that zebra mussels or their larvae could occur at temperatures of the DLWC intake should be ruled out if the DLWC project is to be given serious consideration. Zebra mussel entrapment in the DLWC system could lead to innumerable mechanical problems. Further, mussel entrapment raises the possibility that remedial action such as chemical water treatment or biocides could be used in attempts to eliminate them from the DLWC system. Water treatment or additives in the DLWC system could prove environmentally unacceptable. A comprehensive and conclusive study about the thermal sensitivities of zebra mussels should be completed.

7.2. Entrainment

Plankton, larvae and eggs which cannot be filtered out of the intake water, will be subject to entrainment: organisms travel through the cooling system.

In laboratory and field studies which assessed cooling system designs in the Great Lakes, entrainment caused varied levels of fish larvae, egg and zooplankton mortality, and a reduction in the photosynthetic activity of phytoplankton at temperatures above 8 degrees Celsius.[80] The impact on organisms from entrainment in the DLWC system must be assessed, taking into account the species resident on the lake bottom.

7.3. Impingement

Impingement refers to species or their eggs and larvae being caught on the screen of the intake. The rate of impingement depends on factors such as type of species, intake channel design and intake currents.[81] These factors should be considered when designing the DLWC intake.

7.4. Water Drawdown

The intake design must ensure that water warmer than 4 degrees Celsius from above the 80 m depth is not drawn down into the intake tunnel. Drawing in warmer water will affect the efficiency of the system heat exchangers and produce higher temperatures for the DLWC discharge. It could also increase the chances of introducing zebra mussels or larvae into the DLWC system. Scientists from the Canada Centre for Inland Waters have written a number of papers pertaining to the design of the intake which would prevent drawdown.[82]

7.5. Cleaning DLWC Pipes

Additional concerns that should be addressed are the material used for building supply lines and the eventual need to clean the DLWC pipes and tunnels of calcium, scale and algae. Alternative materials for the pipe must be determined, and then assessed for the possibility and potential impacts of corrosion.

For cleaning water pipes, the Metropolitan Toronto Works Department uses a polyurethane "foam swab" which cleans by friction and is pushed through the system with water pressure.[83]

Some area municipalities use metallic swabs to remove crustaceans from water supply pipes and then re-coat the water mains.[84] Experts who design, manufacture and operate water intake cleaning systems should be consulted to identify any potential problems that could occur with the DLWC pipes.

8. General Observations About the DLWC Proposal

The proposed DLWC project has obvious environmental benefits in two areas: energy savings and its associated carbon dioxide reductions, and the elimination of the need for CFCs and HCFCs which contribute to ozone depletion and global warming. Despite these benefits, the DLWC proposal must also be assessed on criteria which go beyond the narrow focus of the ecological impacts on nearshore ecosystems.

The DLWC proposal remains a technological mitigation measure that will not address the fundamental environmental issues underlying the problems. Pollution Probe stresses that short-term solutions such as DLWC should not become a replacement for long-term strategies. Indeed, there are a number of policy options, regulatory measures and economic tools that can effectively assist in reaching the ultimate goal of environmental protection and ecological integrity.

This section outlines Pollution Probe's major concerns about the environmental problems that have led to the DLWC proposal, several implications for the possible implementation of DLWC, and some future policy directions that deserve consideration regardless of whether or not DLWC is built.

8.1 Problems Leading to the DLWC proposal

Energy Efficiency and Conservation

One of the obvious benefits of the DLWC system is the reduction in electricity needs for cooling systems. However, Pollution Probe cautions that DLWC cannot be used as a justification for relaxing efforts towards improvements in energy efficiency.

The full potential of electrical efficiency is far from being realized in the commercial, industrial and residential sectors. For example, noted energy expert Amory Lovins estimates that by upgrading a typical office fluorescent lighting system, an office can reap a direct energy savings of 70 to 90 percent and an added 35 to 40 percent energy savings on space cooling.[85] Lovins estimates the payback period (at U.S. electricity rates) at less than two years.

Regulations and standards governing the efficiency of electrical equipment is one effective method for both reducing energy use and eliminating the associated environmental impacts of energy production. The introduction of regulations and standards in the commercial and industrial sectors would ensure that these energy consumers come closer to meeting their efficiency potential.

In addition to equipment, current office design is closely allied with energy inefficiency. Most office towers are designed with the objectives of limiting short-term financial costs rather than assuring long-term environmental sustainability. As a result, energy use receives little consideration in the planning stage. While it is impractical to tear down existing office towers in Toronto, significant energy savings could be assured if new buildings are designed with energy efficiency as a mandatory criteria.

8.2 Implications for Implementing the DLWC Proposal

Dilution

The DLWC system would act as a giant dilution mechanism, taking relatively clean deep lake water and discharging it into contaminated water bodies. Dilution has become an end-of-the-pipe solution for mitigating the environmental impacts of pollutants and chemicals discharged into water ecosystems. The DLWC dilution will give the illusion that water quality has improved to an acceptable level, even though total pollutant loadings will remain unacceptably high. Thus, it is essential to undertake at-source solutions which ensure that contaminated discharges are actually decreasing. The dilution factor must not become the justification for ignoring pollution prevention strategies or, worse, increasing emission levels.

Precedent-Setting

If the DLWC proposal is approved, the first system could set the precedent for the approval of other DLWC systems. While the proposed DLWC system for downtown Toronto may have limited nearshore ecological impacts, additional DLWC schemes could cause significant ecological effects in the Great Lakes.

If the system for downtown Toronto is approved, each additional DLWC proposal must be assessed, taking into account the cumulative stresses on the Great Lakes from all industries and utilities that use the lakes and pollute them in their processes.

Expansion

Although DLWC is still in the proposal stage, there has already been discussion of expanding the system's capacity.[86] This is a premature discussion and could be symptomatic of attempts to substitute technological fixes for problems which require more fundamental responses.

With expansion of the DLWC system, the ecological impacts cited in this report could be magnified and prove excessively damaging. There would also be greater difficulty in monitoring and controlling the process and discharge of DLWC outfall.

Global Warming

Global warming, many scientists say, is a certainty. The Great Lakes, like all other bodies will experience changes as a result of the warming trend. The environmental assessment of DLWC must take into account the potential impacts of global warming and how these impacts would affect the environmental impacts of the DLWC system.

Zebra Mussels

As stated earlier in this report, if DLWC is to receive serious consideration, it must be established, beyond any doubt, that zebra mussels or their larvae do not exist at the depth of the intake tunnel (presently, and after global warming). Invasion of zebra mussels into the DLWC system would prove catastrophic. The subsequent need to treat DLWC water could have numerous negative impacts on the waterfront and lake.

Integration of the DLWC Proposal into Waterfront Activities

The Metro Toronto Waterfront is the subject of a number of studies and undertakings which may be affected by the DLWC system. Therefore, it is crucial for the DLWC proponent to contact the agencies involved and determine how the DLWC water withdrawal and discharge may influence their work. The following should be contacted:

- the Metro Toronto Remedial Action Plan
- the Royal Commission on the Future of the Toronto Waterfront
- the Lake Ontario Toxics Management Plan
- the International Joint Commission
- Cityplan '91
- City of Toronto Central Waterfront Plan
- the Metro Toronto Waterfront Plan
- the Toronto Area Watershed Management Strategy
- the Waterfront Water Quality Improvement Program

8.3 Future Policy Directions

Full-Cost Pricing for Electricity

Full-cost pricing, based on the principle that users bear all the associated costs of generating electricity (including materials extraction, generation, transmission, waste disposal, and mitigation measures for environmental impacts) would encourage energy efficiency and conservation, and further the move toward pollution prevention strategies.

At present, the electricity consumed in Ontario is government subsidized, resulting in artificially-low costs to users. The use of declining block rates also establishes an inequitable situation, in which large electricity consumers are subsidized by small ones.

Such policies and rate structures discourage consumers from adopting energy efficiency and conservation measures. In essence, low electricity prices have made it cheaper to pollute than to conserve.

9. Recommendations

Two endeavours should be undertaken prior to starting the DLWC system:

(1) Smaller-scale cooling alternatives for office towers should be investigated prior to initiating the DLWC project. Holding a competition to find de-centralized alternatives to cool offices and residences in urban areas is one possibility for arriving at these ideas.

(2) State-of-the-art energy efficiency standards for energy-using equipment in offices, including lighting systems and office equipment, should be implemented immediately.

Based on the limited engineering design information provided, and the preliminary analysis of environmental impacts, the Don River and the Inner Toronto Harbour should not be considered as outfall locations for the proposed Deep Lake Water Cooling (DLWC) system. Instead, if the DLWC proposal is to be further investigated, a comprehensive study should be conducted to assess the ecological impacts of placing the outfall in the offshore lake.

Oxygenating the DLWC outfall may be useful to increase the dissolved oxygen content of Lake Ontario water.

Several agencies who are presently working on the Toronto waterfront projects should be contacted to determine how the DLWC system could affect these projects and, conversely, how these projects could affect the DLWC system. These groups include: The Metropolitan Toronto Remedial Action Plan (in particular, to investigate how the DLWC proposal may affect Stage 2 of the RAP process which identifies remedial measures), the Royal Commission on the Future of the Toronto Waterfront, the Toronto Area Watershed Management Strategy and others.

If the DLWC proposal is to be investigated further, fuller assessment of the system and its potential ecological impacts must be carried out. The areas that deserve further study are:

- the variations in flow volume and temperatures of the DLWC outfall;
- changes in flow regime created by the additional flow volume from the DLWC outfall;
- characteristics of the thermal plume created by the outfall;
- the impacts of changes in temperature and flow volume on the physical and chemical characteristics of the nearshore and offshore water;
- further assessment of the possible changes to sediment formation caused by the outfall in the Inner Toronto

Harbour, the Don River and offshore;

- the change in dissolved oxygen content in the Inner Toronto Harbour and the Don River due to the outfall;
- a survey of population and diversity of biota in nearshore and offshore ecosystems;
- the habitat conditions, including thermal preferences and tolerances, of biota in the Inner Toronto Harbour, the Don River and offshore;
- the phenomena of ecosystem surprise and how it relates to the DLWC system; and
- the thermal sensitivities of zebra mussels.

Appendix A

Ontario Hydro's Environmental Studies Sampling Program for the Darlington Nuclear Power Generating Station

TABLE 2

DARLINGTON ENVIRONMENTAL STUDIES SAMPLING PROGRAM

Parameter and Purpose	Sampling Method	Sampling Frequency	Sampling Location
SUBSTRATE MAPPING: to identify spawning habitats and detect large-scale changes	side-scan sonar	once in pre-op (1984); once in post-op	area 2 km east and west from diffuser to 15 m depths and offshore to waste disposal site
SUBSTRATE MONITORING: to measure sedimentation effects on spawning habitats	photography, diver observation and rod measurement	approximately quarterly	selected quadrants (approximately 10, each 100 m^2)
BENTHIC INVERTEBRATE PREDATION: to characterize predation by pelagic fish and detect changes resulting from diffuser currents.	analysis of stomach contents of pelagic fish from mixing zone area; collected by purse seine or lift net	one year in pre-op, 2 unit and 4 unit operation; fish collected quarterly, total 100 in each of 3 years.	mixing zone vicinity and a locati outside the diffuser influence
LARVAL FISH AND EGG ABUNDANCE: to evaluate abundance of coldwater fish eggs and larvae relative to entrainment; assess reproductive success in area of thermal influence	benthic sled, plankton nets; low-volume pump (for eggs).	twice weekly in April and May; one year of pre-op, 2 unit and 4 unit operation; pumping 1 week in December in same years.	along 5 transects centred on mixi zone, to 15 m depth; at intervals of depth above bottom (plankton nets); pumping at selected substrate areas.
LARVAL FISH ENTRAINMENT: to assess rates of larval fish entrainment	plankton nets	twice weekly from April to August, in one year of 2-unit and 4-unit operation	in forebay
ADULT AND JUVENILE FISH ABUNDANCE: to detect significant changes in fish density in mixing zone; to assess year-class strength after vulnerability to entrainment; to detect spawning activity in mixing zone	gillnet, acoustic census	one pair of 24 hour sets, twice monthly in May, July, October, November and once in December; acoustic census quarterly (May, July, November)	Gillnets near intake and mixing zone, Port Darlington and McLaughlin Bay.
ADULT AND JUVENILE FISH IMPINGEMENT : to assess intake effectiveness, and to assess fish losses	trash bin inspection, estimation of numbers, by species	daily	pumphouse
SITE VEGETATION: to assess effects of construction and landscaping	airphoto interpretation, site inspection	annual inspection in July or August	major plant communities on site property
WILDLIFE: to assess effects of construction, habitat change, rip-rap, security fences; detect changes resulting from operation	focal point observations of migratory birds	twice weekly from early April to late May and from early September to late October annually	lake shore, on-site pond
	sightings, listening , flushing, sign observations for nesting birds	two-day survey annually during gull nesting	along shoreline, on-site pond
	focal point observations of wintering waterfowl and gulls	twice monthly from December to March	along shore, mixing zone, forebay
	large mammal sightings, sign observations	in conjunction with other studies above, and, in particular, with wintering waterfowl study	site and surrounding area
TRACE ELEMENTS: to assess the magnitude of trace element concentrations in invertebrates and small vertebrates before and after station operation	collection of soil, surface water, vegetation, soil invertebrates and small vertebrates; analyze for trace element concentrations	triplicate samples collected in spring and fall	site and surrounding area
NOISE: to assess the magnitude of change in ambient noise levels due to station construction and initial operation.	monitor leq (equivalent sound level), L_1, L_{50} and L_{90} (one, fifty and ninety percent levels) using a sound level analyzer	continuous monitoring spanning a weekend (Fri-Mon) with analysis made at one-half hour or one-hour intervals	selected locations around site boundaries

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3. Robert Tamblyn, P.Eng., Engineering Interface Ltd., personal communication, April 1991.

4. Letter from Dr. Farrel Boyce of the Canada Centre for Inland Waters, Environment Canada to Robert Tamblyn of Engineering Interface Ltd., dated April 9, 1991.

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6. Proctor & Redfern Limited, 1991. Report on Civil Engineering Works for Downtown Toronto Deep Lake Water Cooling System, page 1.

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20. MOE, 1988. The Effect of Contaminants Associated with Suspended Sediment on Water Quality in the Toronto Waterfront during 1985, Water Resources Branch, Appendix A, Table B4.

21. MOE, 1988. The Effect of Contaminants Associated with Suspended Sediment on Water Quality in the Toronto Waterfront during 1985, Water Resources Branch, page 1.

22. MOE, 1987. The In-Place Pollutants Program - Vol. III: Phase 1 Studies, Water Resources Branch, page 2.

23. MOE, 1985. Historical Development and Quality of the Toronto Waterfront Sediments - Part 1, Water Resources Branch, page X.

24. MOE, 1987. The In-Place Pollutants Program - Vol. IV: Phase 1 Data Summary, page 18.

25. See: Metro Toronto Remedial Action Plan, 1988. Stage 1: Environmental Conditions and Problem Definition, pages 72 to 125.

26. Taken primarily from: Metro Toronto Remedial Action Plan, 1988. Stage 1: Environmental Conditions and Problem Definition, pages 72 to 125.

27. Brian Whitehead, Water Quality Specialist, Ministry of the Environment, personal communication, April 1991.

28. Dr. Isobel Heathcote, University of Toronto, personal communication, May 1991.

29. The following data was supplied by Melanie Nielson, Head of the Great Lakes Water Quality section of the Canada Centre for Inland Waters, Environment Canada:

date	dissolved oxygen	depth
Aug. 19 '88	13.43 mg/l	90 m
Aug. 19 '88	12.96 mg/l	104 m
Aug. 18 '89	11.72 mg/l	90 m
Aug. 18 '89	11.31 mg/l	104 m
Average:	12.36 mg/l	97 m

30. W.L. Linke, 1965. Solubilities of Inorganic and Metal-Organic Compounds; Volume 2 K-Z, Fourth Edition, American Chemical Society, page 1228.

31. W.L. Linke, 1965. Solubilities of Inorganic and Metal-Organic Compounds; Volume 2 K-Z, Fourth Edition, American Chemical Society, page 1228.

32. The following data was supplied by Melanie Nielson, Head of the Great Lakes Water Quality section of the Canada Centre for Inland Waters, Environment Canada:

date	total phosphorous	depth
Aug. 19 '88	0.0083 mg/l	90 m
Aug. 19 '88	0.0187 mg/l	104 m
Aug. 18 '89	0.0082 mg/l	90 m
Aug. 18 '89	0.0159 mg/l	104 m
Average:	0.0128 mg/l	97 m

33. Loading data from: Metro Toronto Remedial Action Plan, 1988. Stage 1: Environmental Conditions and Problem Definition, page 148; and MacLaren Plansearch, 1990. Measurement of Pollutant Loadings from Tributaries Discharging to Lake Ontario - Metro Toronto Waterfront, report prepared for the Ministry of the Environment.

34. Robert Tamblyn, P.Eng., Engineering Interface Ltd., personal communication, April 1991.

35. Duncan Boyd, Water Resources Branch, Ministry of the Environment, personal communication, April 1991.

36. MacLaren Plansearch, 1981. An Assessment of the Effects of Pickering "A" Nuclear Generating Station on the Aquatic Environment, p.S-1. The report states that when nearshore water temperatures are below 4 C, the plume will mix to the lake bottom, and then be carried by currents (page S-2). The report also states that there are difficulties in measuring the area warmed by a thermal plume because of variations in ambient temperatures.

37. Ontario Hydro, 1981. Biological Investigations to Improve Once-Through Cooling System Designs for the Great Lakes, Report No. 81481, page A-5.

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41. MacLaren Plansearch, 1981. An Assessment of the Effects of Pickering "A" Nuclear Generating Station on the Aquatic Environment, page S-3.

42. Ontario Hydro, 1981. Biological Investigations to Improve Once-Through Cooling System Designs for the Great Lakes, Report No. 81481, pages A5 and A8. See also: MacLaren Plansearch, 1981. An Assessment of the Effects of Pickering "A" Nuclear Generating Station on the Aquatic Environment, page S-2.

43. Ontario Hydro, 1981. Biological Investigations to Improve Once-Through Cooling System Designs for the Great Lakes, Report No. 81481, page A8.

44. Ontario Hydro, 1981. Biological Investigations to Improve Once-Through Cooling System Designs for the Great Lakes, Report No. 81481, page A15.

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46. Ontario Hydro, 1981. Biological Investigations to Improve Once-Through Cooling System Designs for the Great Lakes, Report No. 81481, page F77.

47. Quoted verbatim from: LGL Limited, 1991. Pickering Nuclear Generating Station "B": Environmental Effects: Draft Support Report, page 187. Original reference, Haynes et. al., 1989.

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49. Henry Regier, Ph.D., University of Toronto, personal communication, April 1991.

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Is Deep Lake Water Cooling a "Megaproject"?

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May 20, 1991

This report was prepared for the Deep Lake Water Cooling Investigation Group, and submitted to the Canadian Urban Institute.

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Introduction:

In the 1970s and early 1980s, it seemed obvious to Canada's federal government, to most provincial governments, and probably to the Canadian public that megaprojects -- large, complex projects, many of them designed to extract or convert energy or other resources -- were the solution to many of Canada's major problems. Over the past decade, the contrary view -- that these projects almost invariably are major problems -- has changed from a minority view held by a number of public-interest groups (including Energy Probe) to a widespread and powerful, if not dominant, view in Canadian society. For example, a late-1989 membership survey by the Canadian Federation of Independent Business of over 20,000 of its entrepreneur members found that about 72% of them chose "megaprojects" as a preferred area for government spending cuts, putting them at the very top of the list.[1] Respondents, according to the CFIB report, saw megaprojects -- like the ongoing Lloydminster heavy-oil upgrader in western Canada -- as "high profile support for uneconomic ventures that chiefly benefit politicians and big business."

Developments in Canada and around the world in the last few years concerning nuclear generating stations, large hydroelectric facilities, and other megaprojects, have, if anything, made the public odour of megaprojects even worse than when that survey was
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done.[2]

In this climate, a number of discussions were held between a number of proponents and reviewers of the Deep Lake Water Cooling (DLWC) concept for Toronto[3] and the present author, resulting in a contract to address, preliminarily, the question of whether or not the DLWC deserves the criticisms that have made megaprojects unpopular. Put bluntly, does DLWC deserve to be tarred with the same brush as Hibernia, Darlington B, and China's Three Gorges project? (For the actual terms of reference for this project, see Appendix A.)

While the exercise is inescapably grounded in the actual (more properly, the forecast) features of the DLWC proposal for Toronto, it is also inescapably personal, sociopolitical, and highly debatable. Indeed, one of the main purposes of this exercise is precisely to encourage -- and, with luck, to focus -- discussion and debate on the DLWC concept and proposal.

The general approach has been first (in Section A) to list and categorize the key undesirable features of megaprojects, then (in Section B) to judge the DLWC project, as proposed, against those key features. Where DLWC is found to share those features, there follows a brief discussion of the importance of the feature and how, if at all, that characteristic of DLWC might be mitigated or ameliorated. Finally, an overall, composite, highly subjective grade has been assigned to the DLWC project in each section, ranging from INNOCENT to GUILTY. No attempt has been made to assign weights to these grades, or to combine them in an overall grade. In our view, such an amalgamation is not likely to be productive, especially at this stage of the debate, since different observers representing different interests are likely to disagree even more on the various weights of different than on the grades themselves.

In developing the following list of megaproject features, I have been guided not only by my own, Energy Probe's, and fellow environmentalists' experience with large projects we have opposed, but also by the writings on "large complex projects" of management expert Peter W. G. Morris and by those of energy expert Amory Lovins on "hard" vs. "soft" technologies. It is in my view impossible to divorce the specific characteristics that define "megaproject" from those that characterize a "hard technology" project. Possible or not, these characteristics have been combined in this paper.

Finally, these questions, judgements, and opinions, based as they are on approximately five person-days of analysis and composition, are necessarily preliminary, and are submitted without prejudice to Energy Probe's subsequent and ultimate position on any future more concrete DLWC proposal, fleshed out in an Environmental Assessment document and an EA hearing.

The Relativity Paradox:
In wrestling with this topic, I have repeatedly come face-to-face with a striking paradox, often presented quite clearly in the documents presenting the case for DLWC: While the scale, cost, and several other important characteristics of the proposed DLWC undertaking are extremely large and "megaproject-like", they are often exceeded, if not dwarfed, by the corresponding characteristics of the present cooling system for the buildings in Toronto's core -- most frequently the portion of Ontario Hydro's electricity generating megaprojects which provides the electricity for the chillers! This paradox applies, for example, to DLWC's cost, its lead-time, its water use, and its heat rejection to Lake Ontario. It is tempting to say that the enormity of the DLWC proposal would be difficult even to contemplate, if it weren't for the still larger scale of the status quo!

In principle, this paradox suggests two possible resolutions: (1) DLWC, despite its apparent "faults" of scale, is a step in the right direction, much to be preferred to the status quo, and therefore should be supported; or (2) DLWC should not be supported until an exhaustive search for other alternatives has been carried out and has failed to find a preferable one. It is well beyond the scope of this paper to fully resolve this paradox, which will reappear frequently below and, no doubt, in future discussions of DLWC. It is naturally even farther beyond the scope of this paper to carry out that exhaustive search.[4]

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Section A. What are the key undesirable characteristics of a Megaproject?

A.1 Scale

A.1.1 Large in predicted capital cost (and larger still in actual capital cost)

A.1.2 Large in predicted years of "lead-time" (forecast and especially actual!) from first firm plans to first operation (or to dismantlement, if appropriate) -- therefore subject to high interest and escalation exposures during construction, dependent on accurate forecasts of a number of variables (including demand), vulnerable to strikes and wage demands, and vulnerable to changes in political climate and regulatory requirements.[5]

A.1.3 Large in the size (forecast and actual!) of affected impact zones or spheres of influence, e.g., area affected; number of people, industries, governments, eco-systems, organisms and/or species affected; etc.

A.1.4 Poorly matched in scale and geographic distribution to the end-use demand to be filled. I.e., a megaproject is a
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centralized or centralizing way of meeting the end-use demand. In return for real or assumed economies of scale, centralized projects typically suffer from dependence upon a distribution system whose costs, energy losses, and reliability risks are relatively large compared to those of its own central production facility, and which are often "brittle" -- vulnerable to failure with large consequences. (Because of its importance and its relationship to more than scale, "brittleness" is treated as an independent characteristic below, in sections A.3.8 and B.3.8.)

A.2 Complexity

A.2.1 Technically complex, which generally leads to:

A.2.1.1 Increased likelihood of technical problems during construction and operation.

A.2.1.2 Increased lead-times for whole technologies (as opposed to individual projects) because of the need to take time to scale up, e.g, from "laboratory scale" to "pilot scale" to "prototype scale" to "commercial scale".

A.2.1.3 Increased costs for training, maintenance, etc.

A.2.2 Organizationally complex

A.2.2.1 Dependent upon "exceptional" behaviour from the market-place (e.g., monopoly franchise rights, advance commitments from customers, non-profit status).

A.2.2.2 Dependent upon "exceptional" government action (e.g., promotion, proponency, subsidy, forgiveness from regulation, risk guarantees).

A.3 Other key characteristics of megaprojects[6]

A.3.1 "Capital-intensive" (i.e., a large fraction of total delivered cost is attributable to capital costs) and "labour-efficient" (creating relatively few permanent jobs).

A.3.2 Precedent-setting, first-of-a-kind, unpredictable.

A.3.3 Subject to strong schedule pressures ("window of opportunity").

A.3.4 Susceptible to external uncertainties and disruptions during construction.

A.3.5 Capable of creating relatively irreversible impacts.

A.3.6 Poorly matched in energy quality to the end-use demand to be filled.

A.3.7 Reliant on depletable "capital" of energy/resources, rather than on renewable flows or "interest".

A.3.8 "Brittle" -- i.e., subject to "catastrophic" failure, needing (but often precluding) total backup.

* * *

Section B. Does DLWC share these characteristics? And, if so, what then?

B.1 Scale and DLWC

B.1.1 DLWC is clearly and inherently a large project in its predicted capital cost -- a cost described as "prodigious" in THE CASE FOR FREECOOL, January 24, 1991 (henceforth EIL1991a). For example, its total estimated "final cost" of $611 million[7] is significantly over the $150 million benchmark used for "Major Projects" in two Federal Government studies in the 1980s, even allowing for inflation.[8] (But see "The Relativity Paradox" above.) Actual final costs are of course not yet known, although there seems to be no reason to doubt the qualitative statement on p. 40 of the draft Position Paper for a Lakewater Cooling System for Downtown Toronto (May 10, 1991 - henceforth, EIL1991b): "Large projects have a well known tendency for cost overruns. This project is bound to have its share." GUILTY.

B.1.2 A large project in predicted years of "lead-time" (forecast and especially actual!) from first firm plans to first operation (or to dismantlement, if appropriate) -- therefore subject to high interest and escalation exposures during construction, dependent on accurate forecasts of a number of variables (including demand), vulnerable to strikes and wage demands, and vulnerable to changes in political climate and regulatory requirements. (Many of these features are also discussed below, e.g., in B.3.4.) With a claimed post-approval lead-time (EIL1991b, Figure 44) of 3 or 4 years[9], the actual construction phase of this project is somewhat longer and more vulnerable than many commercial projects, but much quicker than a typical "megaproject". Actual lead-time may, of course, be a different matter. And the time taken for environmental assessment will unavoidably increase some vulnerabilities to external change, while (more avoidably) increasing financing costs.[10] INCONCLUSIVE: THE JURY'S STILL OUT.

B.1.3 Large in the size (forecast and actual!) of affected impact zones or spheres of influence, e.g., area affected; number of people, industries, governments, ecosystems, organisms and/or species affected; etc. Even based on the preliminary study to date, the impacts of the DLWC project would seem to be large, in terms of changes to both the built environment (the streets and buildings of downtown Toronto) and, preliminarily, the natural environment as well (micro-climate, surface water quality and temperature, etc.). It is worth noting, however, that at least one of the predicted large impacts on the natural environment -- a significant lowering of downtown Toronto's outdoor summer air temperature -- constitutes a significant decrease in a currently large human impact on the natural environment. That particular "environmental impact" must surely be considered a change for the better, regardless of one's personal environmental value system. Still, the sheer potential impact of this proposal makes it, in this context, LIKELY GUILTY on the human side, THE JURY'S STILL OUT on the natural environment side.

B.1.4 DLWC is clearly and inherently a relatively centralized way of cooling the buildings in Toronto's core. Its central provision of cool water from the depths of Lake Ontario, distributed through an extensive grid of pipes, will replace the functions of a large number of independent, decentralized electrical chillers -- generally one or more per building. Barring disruption of electrical supply (See "The Relativity Paradox" above, and the discussion of "brittleness" in section B.3.8, below), the present decentralized system is clearly and inherently less prone to total "catastrophic" failure than the proposed DLWC system. Nonetheless, the reliability risks associated with DLWC's distribution system may not exceed the total reliability risks of the status quo, or even of the electricity distribution system itself.[11] Furthermore, it would appear that the distribution system energy losses are relatively small for a megaproject -- especially compared to the electricity distribution losses associated with the present system -- because of the relative proximity (ca. 10 km) of the cooling demand to the cooling supply. Still, the costs of the DLWC project's distribution portion -- including the $166 million costs attributed to customer connections (EIL1991b p. 37), the roughly $90 million cost of branch lines (calculated from EIL1991b p. 35), and the cost of the on-land supply tunnels, valves, drive chambers, etc.[12] -- are clearly a significant part of the total costs and may or may not exceed the attributable costs of the distribution system for the electricity to power today's electrical chillers. GUILTY ON SEVERAL COUNTS, INNOCENT ON SEVERAL.

B.2 Complexity and DLWC

B.2.1 Technical complexity, which generally leads to:

B.2.1.1 Increased likelihood of technical problems during construction and operation. It is difficult to predict confidently the final verdict on this subject because of the precedent-setting, therefore inherently unpredictable, nature of the project. And it is, of course, precisely the final verdict that matters. It is tempting, but much too facile, to conclude that DLWC will be far less prone to surprises than, say, nuclear generating stations (the favourite whipping-boy of virtually all megaproject critics) based on the apparently low-technology nature of DLWC's components. That is because (1) the history of megaprojects like large hydro dams and offshore oil rigs -- each of them composed of equipment as apparently "low-tech" as Deep Lake Water Cooling -- is replete with surprises; (2) early proponents of nuclear stations believed (and convinced others) that their new technology was mostly "just another way to boil water" and it was true in the narrow technical sense, although false in every other sense (including common); and (3) many of the costly surprises in the nuclear business -- including the plunging performance of Ontario's own CANDU stations in recent years -- are as much due to individually minor problems with traditional, non-nuclear, "low-tech" equipment (e.g., heat exchangers, feedwater circuits, generator shafts). The significance of these "low-tech" failures has been magnified by other characteristics of nuclear megaprojects, especially that they are huge, capital-intensive, vulnerable, and inherently hazardous. The fact that Deep Lake Water Cooling apparently shares all but the last of these characteristics should give us pause. MAYBE INNOCENT, BUT THE JURY'S STILL OUT.

B.2.1.2 Increased lead-times for whole technologies (as opposed to individual projects) because of the need to take time to scale up, e.g, from "laboratory scale" to "pilot scale" to "prototype scale" to "commercial scale". This is another aspect where hindsight is 20-20 and unfortunately indispensable to a correct verdict. Toronto's Deep Lake Water Cooling system may turn out to be, in historical hindsight, a small-scale prototype for further, even larger developments of its kind. At any rate, the problems faced by overly rapid "leapfrogging" of demonstrations in other technologies (with nuclear generation probably again the best example) would seem to have no obvious analogy here. On the other hand, it is clearly a major "megaproject" challenge to the DLWC proposal that there is no obvious way to "phase it in" or "start small" -- e.g., the length of the intake tunnel is determined not by the number of presently committed customers, but by the immutable distance from shore to the nearest part of the lake bottom that is deep enough. PRESUMED INNOCENT.

B.2.1.3 Increased costs for training, maintenance, etc. This is apparently not a problem, based on forecasts to date. Zebra mussels may be the biggest unknown that is visible. PRESUMED INNOCENT.

B.2.2 Organizational complexity

B.2.2.1 Dependent upon "exceptional" behaviour from the market-place (e.g., monopoly franchise rights, advance commitments from customers, non-profit status). Generally conceded by DLWC proponents: "It will take the cooperation of may jurisdictions and many Owners to bridge the cost and technical requirements of Freecool but the result should be a world class achievement and a long term benefit to the City.[EIL1991a, p.5]" Indeed, the mere fact that this 10-year-old proposal has not yet been undertaken, despite a number of publicly funded studies and well-prepared approaches to potential developers including major oil companies, Noranda, and Consumers Gas indicates clearly that it has been found to fail traditional market-place tests. E.g., EIL1991b, p.6 concludes that in 1984, "None [of the potential investors] felt that the return on investment justified the risk and none was prepared to finance further investigation." A summary of DLWC's essential features done by Canadian Urban Institute in January 1991[13] comments on the likely impacts of the project's unusual risks on the difficulty of finding both financing and customers. On the other hand, a preliminary review of the sensitivity analyses in EIL1991b would tend to indicate that the project could survive a number of market-place setbacks, most notably slow customer connection rates, moderate construction cost overruns -- although not the more-than-doubling so frequently experienced in megaprojects -- and low usage. LIKELY GUILTY, BUT THE JURY'S STILL OUT.

B.2.2.2 Dependent upon "exceptional" government action (e.g., promotion, proponency, subsidy, forgiveness from regulation, risk guarantees). If the concerns raised and discussed in the preceding section regarding risk and delays are valid (or even perceived to be valid by would-be investors), then the project will not proceed without government action to assume or eliminate risks.[14] LIKELY GUILTY, BUT THE JURY'S STILL OUT.

B.3 Other Defining Characteristics and DLWC

B.3.1 DLWC is clearly and inherently "capital-intensive" (i.e., a large fraction of total delivered cost is attributable to capital costs) and "labour-efficient" (i.e., it is expected to create relatively few permanent jobs). For example, page 32 of EIL1991b states: "It is now apparent that the major cost of lakewater cooling will be amortizing the original investment." The preceding discussion gives information on labour needs and job creation, estimating (p. 21) 10,000 "man years" of up-front local labour to create DLWC, and a staff of five (= 5 "man years" per year) to administer and service the operation. GUILTY.

B.3.2 Precedent-setting, first-of-a-kind, unpredictable. By inspection and admission, GUILTY.

B.3.3 Subject to strong schedule pressures ("window of opportunity"). In EIL1991a, Engineering Interface Limited suggests that "There are several windows of opportunity today." Specifically cited are Ontario Hydro's and Toronto Hydro's need for demand reduction, the phasing-out of CFCs (and subsequently HCFCs) as refrigerants for conventional chillers), and the potential impact of zebra mussels on Toronto's present municipal water supply, but perhaps not on the supply of the much colder deep lake water of DLWC. While these features are presented as advantages to timely action, these "windows of opportunity" can also create great pressures on the management, approval, labour relations, etc., of any large, complex project. GUILTY.

B.3.4 Susceptible to external uncertainties and disruptions during construction. This factor is partly the result of factors already discussed: long lead-time (cf. B.1.2, above), which creates a long period of exposure to disruptions during construction; technical complexity (cf. B.2.1 above), and schedule pressure (cf. B.3.3 above), which make time-consuming disruptions more likely and more painful, respectively; capital intensity (cf. B.3.1 above), which imposes large financial costs of delay during construction (both through interim financing, estimated on pp.4 and 37 of EIL1991b, and through real cost escalation); and, according to Morris, is ironically compounded by a project's importance to society in social, economic, ecological, and other ways. As EIL1991b p. 39 concedes, "Much can change in the undertaking of a large project." That report performs "sensitivity analyses" on several variables, analyses whose results will certainly be seen differently by different observers. At least to this observer, the project is GUILTY.

B.3.5 Capable of creating relatively irreversible impacts. While an assessment of the environmental and social impacts of DLWC is far beyond the scope of this paper, it would appear that (1) the environmental impacts of constructing DLWC are likely to be more irreversible than those of operating it, and would appear superficially to be less large -- in other words, DLWC's largest environmental impacts may not be irreversible; and (2) while the social impacts of scrapping the status quo cooling arrangement in Toronto's core buildings are technically completely reversible, they may be so expensive to reverse -- especially back to a decentralized system -- as to be effectively irreversible. NOT PROVEN GUILTY, BUT SUSPECT -- ESPECIALLY ON THE HUMAN/SOCIAL SIDE.

B.3.6 Poorly matched in energy quality to the end-use demand to be filled. By tapping a natural energy sink (in pop-speak, a source of "coolness") that is at precisely the temperature needed to accomplish the job at hand, Deep Lake Water Cooling is an elegant and near-perfect match in energy quality, and an enormous improvement compared to the status quo process which converts premium fuels (coal, uranium, natural gas) into "once-through" steam-turbine-electricity, which is converted in turn to "coolness" in electric chillers. ABSOLUTELY INNOCENT!

B.3.7 Reliant on depletable "capital" of energy/resources, rather than on renewable flows or "interest".[15] According to the preliminary analyses, the supply of 4°C water in the depths of Lake Ontario is -- certainly at present -- a renewable resource, unlike virtually all the electricity that Deep Lake Water Cooling would replace. Under severe climate-change scenarios, this renewability could conceivably disappear. INNOCENT.

B.3.8 "Brittle" -- i.e., subject to "catastrophic" failure, needing (but often precluding) total backup. See the discussion on centralization in section B.1.4, above. But (see again "The Relativity Paradox" above) the status quo is also becoming increasingly brittle: Recently, the provision of electricity for cooling in Toronto's core has already been subject to "voluntary" supply disruptions in summertime, prompted by extreme weather and three key facts: (a) Toronto Hydro's electrical load hits its annual peak in the "dog days" of summer, driven by the city's large and growing cooling load; (b) as the weather gets hotter and more humid, and the demand for building chilling rises, the electricity-to-cooling efficiency of traditional "air-source" electrical chillers generally falls, compounding the impact on electrical demand (cf., e.g., EIL1991b, Figure 27); (c) as ambient air (and lake surface) temperature rises, the generating and power-handling capacity of several key Hydro-system components (including Toronto Hydro's transformer stations) decreases.

These causes of growing unreliability and "brittleness" in the provision of summer electricity in Toronto suggest to this reviewer a number of related questions: (1) Could Toronto Hydro adapt any of its transformer stations to use DLWC to cool them at least in summer, when they are most heavily loaded and least well cooled by ambient air? (2) Has Ontario Hydro considered using Deep Lake Water Cooling for its fossil and/or nuclear generating stations? An improved source of cooling would translate directly into increased capacity at those stations, whose maximum electrical output is directly proportional to the difference in temperature between the high-pressure side of the turbines and the low-pressure side of the turbines, which is cooled by heat-exchange with near-surface lake water. Leaving aside the technical or economic feasibility of such a scheme, its deep-lake impacts would likely dwarf (even) those of the current DLWC proposal. In fact, paradoxically, the more technically and economically attractive this proposal turns out to be, the more Toronto's DLWC scheme will naturally be seen as a potentially dangerous precedent -- "the tip of the iceberg" or "the thin end of the wedge" -- demanding prior careful thought in proportion to its importance as a precedent, not just in proportion to its direct impacts. (Recently, several relatively small and apparently benign exports of Canadian fresh water to the United States have become subject to precisely this kind of pressure.)

There are several other intriguing questions related to "brittleness" in this regard: (1) Do recent geological findings -- specifically the discovery of a NE-SW aeromagnetic lineament running across Lake Ontario from Pickering to the Niagara region, and apparently associated with a fault that may well be active and susceptible to major earthquake activity -- suggest a seismic threat to the integrity of DLWC as planned? And if so, are there affordable modifications that would address that threat? and (b) Has any assessment been made of the cost of protecting the DLWC project from a loss of electrical supply? Would natural gas not in any case be more economical as a prime mover (with some backup fuel stored on-site) than electricity, especially if the "waste" heat from gas-fired pumps could be used profitably, e.g., for the TDHC system? I note that the TDHC system itself is designed to ensure continuous heat provision "even in the event of an electrical blackout or natural gas supply failure."[16] Especially if an increasing proportion of Toronto's buildings protect themselves from electrical blackouts with standby (or even routine) generation capacity, failure of DLWC may become one of the dominant risks to the summer inhabitability of the buildings in the city core. In summary, PRETTY GUILTY.

Summary and Conclusions

DLWC does share many key undesirable characteristics of megaprojects, especially, it would seem, in the economic, social, and management areas, and perhaps less so in the strictly environmental area -- although the projects environmental impacts are still much more poorly characterized than its "human" impacts. Many of the criticisms in the economic, social, and management areas can probably best be silenced by finding a private-sector proponent willing to accept the previously discussed problems in return for the promised benefits. Failure to do so will call into question any academic "proof" that these problems are "manageable" or "acceptable".

On the other hand, DLWC, as planned and forecast, is far from "your typical megaproject". Specifically, it is geographically much smaller, much less expensive, much shorter lead-time, much more thermodynamically elegant, and apparently much less disruptive environmentally than virtually any of the energy megaprojects that have become famous in the last decade or two.

Perhaps most intriguing, DLWC is apparently less undesirable on many counts than the status quo cooling system in the proposed DLWC service area, whose energy is now provided by classic megaprojects lacking in virtually any of DLWC's redeeming features. This comparison cannot logically justify unqualified support for DLWC, especially in light of its own undesirable features (and especially since the status quo itself is in flux, likely for the better), but it does suggest the need for further exploration of preferable alternatives to the status quo, of which DLWC may eventually turn out to be the best.

Appendix A: Terms of Reference

The questions that needs to be addressed, and form the subject of the requested paper, are generally:

A. What are the essential characteristics of so-called "megaprojects" that generally have generally raised public and public-interest-group opposition to them, or caused other problems or challenges not frequently found in smaller undertakings?

B. Which, if any, of any of these essential characteristics of megaprojects does the proposed undertaking ("Freecool") share?

C. If there are shared characteristics, how serious, how inherent, and how amenable to amelioration or mitigation are they?

D. How might these shared characteristics, if any, best be ameliorated or mitigated?

Notes

(1) "Entrepreneurs would drive axe into megaproject, UI spending" by Colin Langedoc, Financial Post, December 27, 1989.

(2) For example, in Canada, the planned second phase of the James Bay project has come under unprecedented pressure; Ontario Hydro's CANDU nuclear stations have turned, visibly, from a source of system reliability and cost stability to a source of unreliability and cost increases, and have come under political as well as public pressure; federal funding to the OSLO oil-sands megaproject has been discontinued. Elsewhere, the privatization of England's electricity system has subjected Crown utility accounting for nuclear megaproject costs to public ridicule, virtually eliminated nuclear megaproject expansion, and decreased the present and future use of coal megaprojects; and the 1992 unification of European markets for electricity ~~are~~ is already widely expected to prohibit French government practices that make its public utility's nuclear megaprojects appear cost-competitive.

(3) including Metro Councillor Richard Gilbert, Canadian Urban Institute's Gillian Mason, and Toronto District Heating Corporations's Kevin Knox.

(4) It is worth mentioning here that the driving energy for the status quo cooling system for downtown Toronto is, as EIL suggest, primarily one or more of Ontario Hydro's coal-fired

megaproject stations, which are presently "on the generation margin" during virtually the entire year, including the summer cooling season. But that part of the status quo is changing: (1) Ontario Hydro itself is proposing to install relatively small-scale, natural-gas-fired gas turbines -- which will at least be convertible to high conversion efficiencies -- for "peak" or "on the generation margin" use, which will partly supplant these coal megaprojects at smaller scale and higher efficiency; (2) several thousand Megawatts of privately-owned and -operated generation capacity -- virtually all of it highly efficient, cost-effective, and "non-megaproject" -- are poised to come on-line in Ontario, and virtually all of Ontario's new generation will, in our view, come from this source if the institutional biases in favour of Hydro-owned megaprojects are struck down; and (3) a major 2-3-year Environmental Assessment hearing has recently begun, capable of significantly advancing Ontario's progress away from coal and nuclear megaprojects.

(5) The preceding list of lead-time impacts is paraphrased from Amory B. Lovins, Soft Energy Paths, New York, 1977, p. 94.

(6) These consist of Morris's "volatility" characteristics, several "hard path" characteristics from Lovins, and a few from Energy Probe.

(7) Calculated on p. 37 of EIL1991b.

(8) The two reports of the Major Projects Task Force, which consisted of Bob Blair and Shirley Carr.

(9) The three-year estimate depends upon the acceptability of a (public) proponent beginning "Final Engineering" before receiving final Environmental Approval". Recent experience with Ontario Hydro's planned pre-approval expenditure of $240 million on "pre-engineering" of its next CANDU nuclear station -- expenditures recently stopped by Ontario Government proclamation in response to public pressure -- strengthens this reviewers conviction that such practice is not acceptable. Without this overlap, the post-EA lead time in Figure 44 becomes 4 years.

(10) In general, the increase in financing cost from delay is a function of how much money has already been "sunk" when the delay occurs. Thus, keeping the pre-approval engineering expenditures to a minimum, while slightly delaying the final completion date of the project, may well decrease total vulnerability.

(11) In this context, "distribution system" includes both "transmission" and "distribution", as these words are traditionally used in the electricity business.

(12) In the version of EIL1991b I have (without Appendices), I don't see a disaggregation of the "on-land" and the "lake" portions of the supply/return system.

(13) A PROPOSAL TO MANAGE A CONFERENCE AND ASSOCIATED PROCESSES ON THE SUBJECT OF FREECOOL: A DISTRICT COOLING SYSTEM FOR DOWNTOWN

TORONTO BASED ON COLD WATER DRAWN FROM THE DEPTHS OF LAKE ONTARIO, Canadian Urban Institute, January 28, 1991, p. 5.

(14) For several reasons, it seems inconceivable that this project could escape full Environmental Assessment Act scrutiny, even if it were pursued as a purely private project, as seems unlikely. In fact, the promoters freely concede the need for a fairly extensive environmental review -- 2.5 years in the base case, extending to 6 years in the "slow track" sensitivity case -- in EIL1991b, *e.g.*, Figure 44.

(15) This feature is a characteristic -- some would say a peripheral characteristic -- of Lovins's "hard technologies" rather than a key definition of megaproject. Indeed, large hydro dams like James Bay 2, Itaipu, Three Gorges, etc., are clearly innocent in this particular regard, yet are among the world's most fiercely opposed megaprojects -- and considered "hard path" by Lovins himself, on many of the other grounds listed here.

(16) TDHC brochure, EFFICIENCY THROUGH DISTRICT HEATING

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DEEP LAKE WATER COOLING:

COST RECOVERY AND OWNERSHIP ISSUES

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Introduction

This report analyses the advantages and disadvantages of alternative cost recovery and ownership regimes for a deep lake water cooling (DLWC) system that might serve the buildings in the downtown core of the City of Toronto. The report is divided into the following sections: cost recovery issues; ownership issues; environmental regulation issues and conclusions.

Under the cost recovery heading the merits of financially self-sustaining and financially non-self-sustaining DLWC systems will be discussed. In addition, the pros and cons of alternative methods of subsidizing a financially non-self-sustaining DLWC system will be analyzed.

The second part of the report will analyze the advantages and disadvantages of the following ownership regimes for a DLWC system to be operated in the City of Toronto namely: 1) a municipal corporation; 2) Toronto Hydro; 3) a provincial crown corporation; 4) Ontario Hydro; and 5) a business corporation.

The third part will analyze the implications of the Environmental Assessment Act approval process. The report will close with a list of our principal conclusions.

Finally, the authors want to note that they are not taking a position as to whether a DLWC system for downtown Toronto is or is not in the public interest.

PART 1: Cost Recovery Issues

1.1 A Financially Self-Sustaining DLWC System

A DLWC system is financially self-sustaining if it recovers its total financial costs from its customers over its life-cycle. Systems or services that have the capacity to be financially self-sustaining are typically required to be so. However there are a number of important exceptions to this rule (e.g., medical services, universities, highways).

If a DLWC system is potentially self-sustaining then it would be fair to recover its total costs from its customers since their total benefits from consuming DLWC will exceed their total costs.

However, if DLWC displaces electric cooling then the supply of DLWC will provide economic and environmental benefits (e.g., reduced electrical generation, transmission and distribution capacity, reduced nuclear wastes, reduced carbon dioxide and CFC emissions) that are not confined to the tenants of downtown office towers. Thus, even if DLWC is potentially financially self-sustaining, it might be appropriate to subsidize its costs and hence rates in order to encourage the displacement of electric cooling. The subsidy would be justified if: 1) the subsidy-induced displacement of electric cooling is a cost-effective means to reduce electric supply capacity, carbon dioxide emissions, nuclear wastes and/or CFC emissions; and 2) it is in the public interest to achieve these reductions.

In the following section we will discuss a number of options for providing subsidies to DLWC.

1.2 A Financially Non-Self-Sustaining DLWC System

If a DLWC system is not expected to be financially self-sustaining or if it is determined that the system should not be financially self-sustaining then there are at least four cost recovery mechanisms that can be considered.

First, all municipal, provincial and/or federal taxpayers could be required to subsidize DLWC's annual deficit (the beneficiary pays principle).

Second, with an appropriate amendment to the Local Improvement Act, the City could impose a special compulsory charge on the rateable property of DLWC's actual and potential customers to recover some or all of DLWC's costs (the polluter pays principle).

Third, the subsidy could be provided by Ontario Hydro and/or Toronto Hydro (the utility pays principles).

Finally, the subsidy could be provided by a combination of the above options.

The Beneficiary Pays Principle

If DLWC is being subsidized in order to reduce nuclear wastes, carbon dioxide and CFC emissions then everyone in the world, including future generations, will benefit from DLWC. According to the beneficiary pays principle, pollution reduction or mitigation should be financed by its beneficiaries. Thus, according to this principle, DLWC should be subsidized by all present and future citizens of the world. However, it is impossible to require future generations to pay for today's pollution abatement. Furthermore, it is not realistic to assume that non-Canadians might subsidize DLWC.

In the absence of a global subsidy for DLWC it could be appropriate, according to the beneficiary pays principle, for the federal government to subsidize DLWC since all Canadians will receive environmental benefits from DLWC. On the other hand, the Government of Canada might establish nuclear waste, carbon dioxide and/or CFC emission reduction targets for Canada and sub-targets for the provinces. Under this scenario, if each province was given responsibility for achieving its target then, according to the beneficiary pays principle, it could be appropriate for Ontario to subsidize DLWC.

Finally, since the citizens of the City of Toronto and the Municipality of Metropolitan Toronto will receive environmental benefits from DLWC, the beneficiary pays principle could justify a City and/or Metropolitan Toronto subsidy.

In short, the beneficiary pays principle entails that individuals and corporations have a right to pollute and hence must be paid not to exercise this right. Needless to say, the use of the beneficiary pay principle to resolve all environmental issues would imply a massive increase in government spending.

The Polluter Pays Principle

The opposite of the beneficiary pays principle is the polluter pays principle. According to the polluter pays principle, polluters should pay for the privilege of polluting. Furthermore, according to this principle, society should require polluters to pay for measures that are necessary to reduce or mitigate the environmental costs of their actions. [1.]

The polluter pays principle has been adopted by the Organization For Economic Co-Operation and Development (OECD) member countries:

> "In 1985, OECD Member countries adopted the "Declaration on Environment Resources for the Future", in which they undertake to seek to introduce more flexibility, efficiency and cost-effectiveness in their pollution control measures in particular through a consistent application of the Polluter-Pays Principle..." [2.]

If the prime objective of DLWC it to reduce the environmental costs of cooling Toronto's downtown office towers then the polluter pays principle would justify a policy that required the owners and/or tenants of buildings in the downtown core with air conditioning to finance the subsidy.

That is, the polluter pays principle would justify a special charge on all downtown buildings that have air conditioning. Ideally, such a charge should be directly proportional to a building's annual cooling requirements for the following reasons. First, the greater is a buildings annual cooling requirement the greater is its responsibility for total downtown Toronto cooling-related pollution. Second, if the charge is directly related to the buildings' cooling requirements then building owners will have a greater financial incentive to design or retrofit their buildings in a manner that will reduce their total cooling needs.

The Utility Pays Principles

In principle, a DLWC subsidy from Ontario Hydro and/or Toronto Hydro could be justified on the grounds that it will lower electricity rates.

Ontario Hydro's incremental cost of adding new electrical generation and transmission capacity exceeds its average cost of supplying electricity. Thus as Ontario Hydro increases its generation and transmission capacity its average costs and hence rates will rise. As a consequence, electricity demand side management measures can benefit all of Ontario Hydro's customers by reducing the need for new electricity supply and the attendant rate increases. Thus, in principle, an Ontario Hydro subsidy to DLWC could reduce the demand for electricity and lower Ontario Hydro's rates. To be specific, as long as the subsidy, per kwh of subsidy-induced reduction in demand, is less than the difference between Ontario Hydro's incremental and average costs of supplying a kwh then all of Hydro's customers will benefit from the subsidy.

Similarly, if Toronto Hydro's incremental distribution costs are greater than its average distribution costs then, in principle, a Toronto Hydro subsidy to DLWC could benefit all of Toronto Hydro's customers.

Alternatively, a DLWC subsidy from Ontario Hydro and/or Toronto Hydro that raises electricity rates could be justified on environmental grounds.

The Ontario Round Table on Environment and Economy has articulated six guiding principles for achieving sustainable development. According to the second of its principles, full cost accounting, the prices of all natural resources should equal their full economic and environmental costs:

> "To prevent overuse and exploitation, all prices ideally should incorporate environmental, social, and resource depletion costs. This will provide economic incentives for wise resource use...
>
> This principle demands that natural assets be fully valued to ensure proper use and allocation, and to make certain that the beneficiary of the activity pays the full price including the cost of any environmental damage and resource use"[3].

The Round Table has also noted that full cost pricing should be implemented in a way that minimizes its adverse effects:

> "The challenge is to define and implement the principle in a way that minimizes adverse effects on individuals and groups, or on our international competitiveness."[4].

The price of electricity in Ontario does not include its full economic and environmental costs. Thus a strategy to implement full cost pricing for electricity and to minimize its adverse impacts is required. A DLWC subsidy from Ontario Hydro and/or Toronto Hydro could be part of such a strategy. For example, Ontario Hydro and/or Toronto Hydro could establish full cost pricing for electricity and minimize the adverse effects of such a policy by adopting the following measures. First, gradually raise the price of electricity by x% per year until its price equals its full economic and environmental cost. Second, use the resulting excess revenues (i.e., revenues that exceed the financial cost of electricity supply) to subsidize energy conservation and alternative energy investments. That is, by using the excess electricity revenues to finance energy efficiency and renewable energy, the Hydros could minimize the impact of higher electricity prices on their customers' total energy bills. (For example, a 100% rise in energy prices might not raise a consumer's total energy bill if an energy efficiency investment has reduced its energy consumption by 50% or more.) Furthermore, such a subsidy programme would be consistent with the polluter pays principle since electricity consumers would be financing investments to reduce electricity-related pollution.

PART 2: Who Should Own DLWC?

2.1 Municipal Corporation

From a municipal perspective, there are at least three potential benefits from municipal ownership of DLWC. First, it might be a means of reducing municipal taxes for the City of Toronto and/or the Municipality of Metropolitan Toronto. To be specific, if in the long run, the average total cost of a unit of DLWC is significantly lower than the average total cost of electric and natural gas cooling then the DLWC system could earn a substantial profit by setting its rates above its costs and the profits could be used to reduce the costs of other municipal services. Furthermore, as long as the total cost of DLWC is less than the total cost of the next cheapest alternative, both municipal taxpayers and DLWC's customers will benefit from DLWC's existence.

Second, municipal ownership would give the City of Toronto and/or Metropolitan Toronto direct control over the DLWC system.

Third, if a municipally controlled public utility is created to own and operate a DLWC system it may be appropriate to amalgamate the DLWC public utility with the Toronto District Heating Corporation for the following reasons. First, to achieve economies of scale in operation. Second, it might be possible to use the heat in DLWC's return water for district heating.

On the other hand, municipal ownership implies municipal liability for DLWC deficits. It is important to remember that even if DLWC's actual and potential customers are subject to a compulsory tax and/or if DLWC is subsidized by the Province of Ontario and/or Ontario Hydro, DLWC's revenues (costs) could be less (greater) than expected.

2.2 Toronto Hydro

There are at least two reasons why it could be appropriate for Toronto Hydro to own and operate a DLWC system as opposed to a stand alone municipal corporation. First, if Toronto Hydro has superior management it might be in the public interest for Toronto Hydro to own and operate the system. If this were the sole reason for Toronto Hydro ownership of DLWC then presumably its revenues and costs should be kept separate from Toronto Hydro's electricity revenues and costs. Under this scenario DLWC's profits and/or losses would accrue to/be borne by the City of Toronto and/or Metropolitan Toronto.

Alternatively, it might be deemed appropriate for Toronto Hydro to own and operate the DLWC system on the grounds that it is an electricity demand-side management programme. Under this rationale, DLWC's losses/profits should presumably be borne by /accrue to Toronto Hydro.

According to section 95a of the Power Corporation Act, Toronto Hydro cannot borrow funds to finance demand-side management programmes. As a consequence, in the absence of an appropriate amendment to the Power Corporation Act, Toronto Hydro would have to finance DLWC's capital costs on a pay-as-you-go basis. That is, it would have to raise its electricity rates dramatically during the years in which the DLWC system is being constructed. On the other hand, its rates could fall dramatically at the end of the construction period. Furthermore, electricity rates could also decline if and when DLWC made a profit.

2.3 A Provincial Crown Corporation

Unlike the City of Toronto and/or Metropolitan Toronto, the Province of Ontario can impose a special tax on DLWC rates. Thus provincial ownership of DLWC is not necessary in order to ensure that the province shares in the net economic benefits that may flow from DLWC.

From a municipal perspective, the prime benefit of provincial ownership is that it could absolve the municipal governments from liability for any DLWC deficits. (Needless to say, this is presumably not a benefit from the perspective of the Treasurer of Ontario.) On the other hand, provincial ownership also denies municipal governments the opportunity to share in DLWC's profits.

If the debt of the corporation is guaranteed by the provincial government its borrowing costs will be less than if its debt was guaranteed by the City of Toronto and/or Metropolitan Toronto. As a result a provincially-owned DLWC system could potentially earn a higher profit than a municipally-owned corporation. Similarly, a provincially-owned DLWC system could potentially earn a higher rate of profit than a privately-owned corporation.

2.4 Ontario Hydro

If a DLWC system is built to serve downtown Toronto then it is reasonable to assume that it could receive a large capital contribution from Ontario Hydro on the grounds that it is an electricity demand-side management investment. As a consequence, a strong prima facie case could be made that Ontario Hydro should be a joint or the sole owner of a DLWC system. However, there are also a number of reasons why partial or complete Ontario Hydro ownership of a Toronto DLWC system might not be in the public interest. First, Ontario Hydro has provided subsidies for numerous demand-side management investments without receiving equity ownership. Thus the principle of consistency would suggest that Ontario Hydro should not receive an equity interest in a Toronto DLWC system simply as a result of a capital contribution. Second, if Ontario Hydro obtains an equity interest in DLWC it may become legally, morally and/or politically liable for any unanticipated DLWC deficits. Third, since Ontario Hydro is already a very large and powerful corporation it may not be in the public interest to unnecessarily increase its size.

From a municipal public finance perspective, the costs and benefits of Ontario Hydro DLWC ownership are no different from the costs and benefits of DLWC ownership by a stand alone provincial crown corporation. However, from a Province of Ontario public finance perspective, Ontario Hydro ownership would be preferable since it would absolve the Treasurer of Ontario from liability for unexpected DLWC deficits.

2.5 Business Corporation

A prime potential benefit of the operation of a DLWC by a business corporation (eg. a subsidiary of Consumers' Gas) is that it could relieve municipal and provincial taxpayers of any liability for any unexpected DLWC deficits. Conversely, however it would deny the City and/or Metropolitan Toronto the opportunity to share in the potentially large economic benefits that will flow from DLWC.

On the other hand, a profitable business corporation type DLWC system would provide corporate income tax revenues for the Governments of Ontario and Canada. Furthermore, the Province of Ontario could increase its share of DLWC's economic benefits by imposing a special surcharge or tax on DLWC's rates. As long as the tax inclusive cost of DLWC is less than the cost of the next cheapest alternative then the privately-owned DLWC corporation, building owners and tenants, provincial and federal taxpayers will all benefit from DLWC.

In addition, if DLWC is a business corporation then its Board of Directors may impose greater cost control discipline on its managers than if it is publicly-owned.

However, if the DLWC system is a business corporation and if the average total cost of DLWC is significantly less than the average total cost of the next cheapest alternative then its prices may have to be regulated in order to prevent it from earning excess profits. A logical agency to perform this task would be the Ontario Energy Board.

Ironically a potential liability of a business corporation DLWC system is that its rates might be too low. In the absence of a special provincial tax on DLWC, the cost of DLWC might be significantly lower than the next cheapest alternative. If this were to occur then property owners located outside of DLWC's service territory would vigorously lobby for an expansion of the geographical size of DLWC's service territory. Furthermore, DLWC's shareholders would also support such a request since it would increase DLWC's rate base (capital investment) and hence potential profits. The mutual self-interest of these two groups might make the expansion of the DLWC system politically irresistible. However, such a result would not be in the public interest if alternative options (e.g., better built or retrofitted buildings) could meet Toronto's cooling needs at a lower social cost.

On the other hand, in theory at least, if DLWC was municipally-owned then the City could dampen political pressure to expand the DLWC system by raising its rates until the cost of DLWC is equal or almost equal to the cost of the next best alternative. In practice, however, due to political pressure from building owners, municipal councils may be unwilling to raise DLWC's rates.

PART 3: Environmental Regulations

The degree to which a DLWC system would be subject to environmental regulations could depend on the type of ownership. If the DLWC was owned by the public sector it would probably be subject to a full Environmental Assessment (EA) under the Environmental Assessment Act (EAA). Although there are exemptions from the EA process available to municipalities it is doubtful if the DLWC would fall within the exemption or be exempted by the Minister of the Environment. A private sector business corporation ownership would not be subject to the EAA as currently drafted; however, the Minister of the Environment could designate it as subject to the Act at the request of the public as was the case with privately-owned waste landfill sites and transfer stations.

PART 4: Conclusions

Our analysis has revealed that there is a wide array of cost recovery and ownership options for a downtown Toronto DLWC system. In this section we will state our principal findings.

First, if a DLWC system can and should be financially self-sustaining then, by definition, it should recover 100% of its costs by means of voluntary customer user fees.

Second, if environmental benefits justify a financially non-self-sustaining DLWC system then Organization For Economic Co-Operation and Development and Government of Ontario policies imply that the DLWC system should be financed in a manner that is consistent with the polluter pays principle. Ideally, according to the polluter pay principle, if a DLWC system is built to reduce downtown Toronto cooling-related pollution then all of its actual and potential customers should be required to finance its deficit. Furthermore, each actual and potential customer's share of the deficit should be proportional to its cooling requirements and hence cooling-related pollution. An amendment to the Local Improvement Act would be required in order to permit the recovery of the capital costs of a DLWC system from its potential as well as actual customers.

Alternatively, a DLWC system subsidy from all the customers of Toronto Hydro and/or Ontario Hydro could also be justified according to the polluter pays principle since DLWC will reduce electricity-related pollution.

Needless to say, under the latter alternative the link between the polluter and the payer it less direct than under the former alternative. As a

Needless to say, under the latter alternative the link between the polluter and the payer it less direct than under the former alternative. As a result, the latter alternative will be more attractive to tenants and building owners in downtown Toronto.

Third, from a federal public finance perspective, a business corporation privately-owned DLWC system would be the preferred alternative for if the system is profitable it will pay federal corporate income tax whereas a publicly-owned municipal or provincial corporation would not.

Fourth, from a provincial public finance perspective, a profitable business corporation DLWC system could be preferable to a municipally-owned system since it would automatically pay provincial corporate income tax. Moreover, if the system is profitable a provincially-owned system would be preferable to a privately-owned business corporation system since the former would not have to pay federal taxes and hence all the profits could accrue to the Treasurer of Ontario. Needless to say, provincial ownership also exposes the Treasurer to the risk of unexpected DLWC deficits.

Fifth, from a municipal public finance perspective, municipal ownership would be the preferred option if DLWC is expected to be profitable. For municipal ownership is the only means by which municipal governments could directly reap a share of the net economic benefits of DLWC.

Sixth, if DLWC is not expected to be profitable then, from a public finance perspective, all governments will prefer the option which will minimize their liability for DLWC's expected and unexpected deficits.

Seventh, tenants and building owners in downtown Toronto will prefer the ownership option which will minimize their total cost of DLWC. However, since there is no necessary relationship between the alternative ownership options and the level of DLWC rates, it is impossible to draw firm conclusions as to which ownership regime would best serve the financial self-interests of building owners and tenants.

Eighth, from a strict legal viewpoint only a publicly owned DLWC would be subject to an EA; however, in practice a privately owned DLWC would probably be subject to an EA.

Endnotes

1. According to an Organization for Economic Co-Operation and Development (OECD) report:

> "The PPP principle as defined by OECD means that the polluter should bear the cost of measures to reduce pollution decided upon by public authorities to ensure that the environment is in an "acceptable state".

OECD, Economic Instruments for Environmental Protection, (Paris: OECD; 1989), p. 27.

2. ibid.

3. Ontario Round Table on Environment and Economy, Challenge Paper, (Queen's Printer for Ontario, 1990), p. 6.

4. ibid.

1

LAKE WATER
COOLING
FINANCE/ORGANIZATIONAL
CONSIDERATIONS

FUNDING NEEDS

- $25 MILLION ENVIRONMENTAL ASSESSMENT (EA) ACT REVIEW
  - RISK INVESTMENT
  - MAY GET A NO ANSWER
  - MAY GET A YES WITH CONDITIONS WHICH PRECLUDE ECONOMIC SYSTEM

- $700 MILLION NEEDED FOR FULL IMPLEMENTATION OF THE LAKE WATER COOLING SYSTEM
  - COULD BE A SELF-FINANCING UTILITY IN ITS MATURE FORM
  - PROBLEM IS TO BRIDGE THE CASH FLOW POSITION DURING CONSTRUCTION AND EXPANSION OF THE DISTRIBUTION GRID

FUNDING SOURCES

- E.A. RISK MONEY
  - MINISTRY OF ENVIRONMENT
  - MINISTRY OF ENERGY
  - MINISTRY OF HOUSING
  - ONTARIO HYDRO
  - METRO
  - CITY
  - FED'S (EMR/CMHC)

- DOVETAIL WITH SAUNDER'S E.A. HYDRO SUPPLY/DEMAND

- CAPITAL MONEY
  - PRIVATE MONEY (TAX WRITE-OFFS)
  - HYDRO GRANTS
  - HYDRO EQUITY PARTICIPATION
  - PROVINCIAL EQUITY PARTICIPATION
  - CONSORTIUM EQUITY PARTICIPATION

CAPITAL FUNDING RISK MITIGATION MEASURES

- ENVIRONMENTAL GROUP SUPPORT COULD REDUCE THE TIME, RISK AND COST OF E.A. PROCESS
- AREA RATING
- LOCAL IMPROVEMENT
- MANDATORY SURCHARGE FOR ALL AIR CONDITIONED BUILDINGS ON THE GRID
- SECURE DEBENTURES ON THE MANDATORY SURCHARGE POWER
- EQUITY POSITIONS
- FIRST RECOUPMENT FOR RISK TAKERS
- PROVINCIAL LOAN GUARANTEES
- ONTARIO HYDRO LOAN GUARANTEES

OWNERSHIP/PROPONENT OPTIONS

- JACK GIBBONS C.E.L.A. STUDY
- HYDRO
- T.D.H.C.
- CITY OF TORONTO
- METRO
- LAKE WATER COOLING CONSORTIUM
- CONTROL TO RISK TAKERS/CAPITAL PROVIDERS TO PROVIDE COMFORT UNTIL FULL RECOUPMENT
- PARTNERSHIPS AND COALITION EXERCISE
- TIGHTEN FOCUS VERSUS MULTI-PARTIED STRATEGIES

SURPLUS REVENUE DISTRIBUTION

- EQUITY PARTNERS
  - HYDRO
  - PROVINCE
  - METRO
  - CITY
- GLOBAL ENVIRONMENTAL FUND
- CONSOLIDATED REVENUE FUND
- ENERGY CONSERVATION FUND
- R & D/INNOVATION FUND
- METRO/CITY MUNICIPAL FRANCHISE FEES
- REDUCE HEATING/COOLING COSTS FOR RESIDENTIAL ON GRID

Deep Lake Water Cooling Alternatives

A DISCUSSION PAPER FOR
THE DEEP LAKE WATER COOLING
INVESTIGATION GROUP

PREPARED BY
ALLEN ASSOCIATES

MAY 6, 1991

Introduction

Deliberations on the advisability of the Deep Lake Water Cooling (DLWC) project should take into consideration alternative strategies that could achieve similar ends so as to establish relative costs, environmental impact, and broaden societal implications.

It may also be the case that these alternate means are compatible with DLWC, enhancing its viability. This paper provides a general survey of measures to reduce or displace electrically driven, CFC-based air conditioning in the downtown core.

Objectives

Before discussing alternatives to DLWC, it is necessary to review the major arguments for considering this technology. These are:

1. Means of reducing electrical demand, particularly during summer and winter day-time peaks, are being sought by Ontario Hydro to avoid the high capital and environmental costs of new supply options.

2. The phasing out of CFCs requires expensive conversion of cooling equipment to benign (hopefully) alternative refrigerants with performance penalties that may increase energy demand.

3. Eliminating cooling towers offers the benefits of conserving water, avoiding their chemical additives, and reducing risk of exposure to Legionella bacteria (Legionaire's disease).

4. Many existing commercial/institutional buildings have inadequate cooling plants for the increasing cooling demand imposed by plug loads (e.g. office equipment), necessitating either demand reduction or changes to the physical plant.

Alternatives to DLWC should be considered with respect to their capabilities of meeting some or all of the above.

Load Characteristics

Fundamentally, the need for cooling is to provide suitable conditions for the health, well-being, and productivity of building occupants and the operation of equipment - the latter often requiring more stringent conditions than the former. Only one generation of humanity has experienced the fully air-conditioned built environment - an air-conditioned theatre in the 1950s was considered a sensational promotion. Increased expectations, inoperable windows, architectural liberties, large-scale energy-intensive buildings, and rising temperature and contamination of the urban atmosphere have conspired to create the awesome demand for cooling that is our current challenge. It should be borne in mind that the context of the development of cooling technology and the design of the buildings

that require it, has been one of cheap, abundant supply of energy (with the promise of its getting even cheaper). The last two decades of environmental warnings, international resource conflict, price shocks, supply shortages, catastrophic events, etc., has altered the picture, but we have not yet formulated an adequate response in the design of urban structures.

Before exploring means to reduce cooling demand and alternatives to supplying cooling, it is useful to analyze the load and current practices. The load may be broken into three major components - ventilation, internal gains, and envelope. Ventilation load (i.e. cooling and dehumidifying outdoor air) may range from 90%, as in hospitals, to negligible, as in warehouses, but is typically 30-40% of the total cooling load. Internal gains include people, lighting, equipment, and sometimes space heating, and are typically 1/3 of the cooling load in office buildings, ranging from negligible in warehouses to 90% in equipment-dominated uses (e.g. telephone switching stations). Envelope heat gains via solar gain through windows, conduction, and infiltration make up the remainder. By strategically contending with each contributing element, it is possible to achieve reduction in demand by an order of magnitude in many buildings. Since load reduction measures typically involve the reduction of energy demand for other loads (e.g. lighting, space heating, fan power) there are compound benefits and paybacks. As well, HVAC equipment size and cost is proportionally reduced. Hence, the first priority should always be the optimal exploitation of load reduction potential.

In many respects, mechanical systems have grown to become complex, ineffectual monstrosities with each new modification attempting to rectify the last problem. We now must contemplate "smart" buildings with countless controls, sensors, dampers, valves, pumps, blowers, temperature regulators, heat exchangers, boilers, chillers, and highly skilled pilots. The parasitic load (i.e. energy required by the system itself) may in some cases become the primary load so that we are ending up with machines for the machines' sake. The modern physical plant requires vigilant, highly skilled operators, constant maintenance, and massive energy purchase. They are increasingly more expensive and occupant satisfaction continues to diminish (witness the sick building syndrome). It matters little whether the system selected is a variable air volume (VAV) type, terminal reheat, with or without condenser heat recovery, or incremental heating and cooling fan-coils. This stupendous and ingenious fiasco is not a result of neglect, incompetence, or inadequate resources. Rather, it is the product of rapid growth, the separation of engineering and architecture, professional conservatism due to litigation susceptiblity, and the evolution of commercial equipment. Nothing short of a fundamental and integrated rethink steered by experimental hindsight and environmental foresight can hope to adequately remedy the need for a healthy built environment without destroying our terrestrial one.

Some final comments on the nature of the cooling load problem that pertain to the non-technical, cultural dimension are worth mentioning. The performance parameters to which we design are derived from attempts to translate subjective, culturally-relative, laboratory responses for people into universal attitudinal laws. In the real world of office politics, shifting priorities, and an immeasurable number of contributing environmental factors, it is, at best, a democratically derived compromise that is being designed for. The artificial world of man-controlled virtual realities is failing to convince us that things are o.k. in the universe. Air conditioning is widely seen as a cause of illness and there are certainly objective grounds for such beliefs. Biogens may abound in the equipment. Large differences between indoor and outdoor conditions may result in harmful stress. Temperature constancy, in and of itself, may be unhealthy since we often seek thermal stimulation. It may not be far off that an appreciation for broader issues and shifting preferences will radically alter performance requirements and design objectives.

DLWC being merely an alternate chilled water source is subject to the foregoing considerations as with any other supply option. In fact, the problems DLWC solves extend well beyond geographically feasible applications. Alternatives are to be sought regardless of the advisability of lakewater cooling.

Load Reduction Options

Current and emerging technologies make it feasible to reduce cooling demand by an order of magnitude. The examples discussed here have benefits beyond cooling operating and capital cost savings. Typically, comfort, health, energy usage, and other benefits accrue. A brief survey encompassing measures that pertain to the major components of cooling load should suffice in establishing the technical and economic potential.

Ventilation

Displacement ventilation, a strategy used extensively in Europe and sparsely in North America, improves indoor air quality at less than 1/2 the rate of air change conventionally employed. By cooling and heating radiantly in conjunction with a low conductive envelope, fresh air at about 18^{0}C may be introduced at floor level and by natural convection will carry contaminants to the ceiling for discharge. Avoidance of cross contamination due to recirculated air further improves ventilation effectiveness. Energy analysis indicates a savings potential of at least 66% of ventilation cooling load and, with heat recovery, heating load reductions of 70% for a typical office building. Reduced ventilation rates also lower fan power requirements.

Lighting and Equipment

Lighting is the largest heat gain in many large commercial buildings, not to mention the electrical demand. Recently, office equipment usage has grown to vie with lighting as an internal gain. These internal gains can be largely avoided through design, selection, control, and usage. Cost savings accrue due to reduced electrical usage, cooling demand, and cooling equipment capacity required.

Replacing a four 40 Watt luminaire with two T-8 fluorescent tubes, reflector, and electronic ballast yields a 70% savings. Lowering background lighting levels and providing work surface task lighting cuts a further 50%. Controls for daylight compensation, user demand, and energy management can cut another 50% or more. If comprehensively applied, overall lighting load reductions in excess of 90% are achievable. Considerable movement toward such levels is already underway.

Other electrical loads, such as computers and photocopiers, are capable of similar dramatic improvements, but the electronics industry has not yet emphasized energy efficiency.

Nevertheless, laptops and non-thermal printers are available and use an order of magnitude less energy than their typical office counterparts. It is reasonable to assume equipment efficiency will improve if for no other reason than to reduce overheating susceptibility.

Building Envelope

Envelope upgrades have several benefits in addition to cooling load reduction. Low conduction surfaces and air sealing improve comfort through mean radiant temperature effect, higher permissible humidities, and draft avoidance. If perimeter demand is lowered, the need for core/perimeter differential control is obviated. Daylight treatment of windows may improve the quality of lighting and eliminate glare.

Increasing insulation is an obvious measure, but eliminating thermal bridging in the process can yield substantive improvements. Both interior and exterior retrofits have been successfully demonstrated. Panelized wall systems typically feature thermally broken, RSI 3.5 assemblies with a rigorous air barrier.

High performance glazing options are now available, featuring low emissivity coatings, selective transmittance, gas filling to reduce heat and sound transmittance, low conduction edge spacers, and insulating frames. Windows with insulation values exceeding RSI 1.0, or three times conventional window insulation, and light transmittance twice what has been available for a given shading coefficient are now commercially available. Such a revolution in performance capabilities has not yet been translated into advanced building design, but initial demonstration has been successful.

The combined impact of reduced envelope heat transfer, optimal selection of glazing transmittance properties, and provision for daylighting should result in at least a 75% cooling load reduction potential.

Combined Impact

By tackling heat gain components comprehensively, load reductions of greater than 75% are achievable. There are several implications to such a dramatic change in HVAC requirements. One, already mentioned, is that the perimeter zone may not require separate control, possibly eliminating the need for VAV, terminal reheat, or perimeter consoles. Another is that building thermal mass may be sufficient to carry nighttime cooling through the day, permitting greater free cooling, very small cooling capacity, and/or off-peak operation. The vastly reduced cooling system size results in smaller ductwork, fan and pump power, cooling equipment, etc., saving proportionally on both capital and operating costs.

Cooling Supply Options

Having first exploited all the load reduction potential, it is then appropriate to consider what means of providing cooling is the most attractive, taking into consideration environment, economics, and social factors. We can categorize the options by their energy sources.

Electricity

As previously indicated, a primary motivation for considering DLWC is to avoid new utility peak summer demand and also reduce electrical usage which avoids coal-fired generation, hence greenhouse and acid gas emissions. Nevertheless, electrically-powered compression systems will remain the common technology for some time to come.

Improved compressors, heat exchangers, and controls are boosting efficiencies. Nighttime cool storage, commonly as ice, currently promoted by Ontario Hydro, improves the load factor and avoids new demand. Overall efficiency may be improved by utilizing heat recovery as with run-around heat pumps, exhaust air heat pumps, and rejection to domestic hot water, swimming pools, etc.

Such improvements make electricity more attractive. Even if electrically-based systems prove the most environmentally damaging and have the highest life-cycle cost, their familiarity, infrastructural support, and low initial cost will tend to dominate decision making.

Gas Source

Natural gas, although in apparent copious supply and capable of reducing CO_2 emissions by displacing electricity, is still a source of atmospheric contamination and will require expansion of pipeline capacity. Gas engine compressors and absorption machines are common in Japan and are witnessing rapidly expanding markets in the U.S.. Gas is also used by the Toronto District Heating Corporation and its steam may be used to power absorption cooling equipment. Another option is to use waste heat from gas-fired cogeneration to drive absorption or desiccant coolers.

Unless the ratio of gas-to-electricity prices double, there is little financial incentive to apply direct-fired gas absorption (C.O.P of 1.0). New gas engine plus dual effect absorption equipment can achieve C.O.P.s greater than 2, but capital costs limit their appeal.

Gas-fired cogenerated electricity coupled with space heating and cooling bring economic viability more into line. The relatively constant year-round load of space heat cooling and hot water opens the market for smaller scale cogeneration to include schools, offices, hospitals, and apartments. Electric demand management is doubly beneficial in that heating and cooling loads are avoided and new supply during system peaks is provided.

District heating may be seen as a variant on the above options except that capitalization is by a third party. Hence, initial cost barriers are overcome to some extent.

Renewable Sources

The terms renewable and sustainable are virtually inter- changeable; hence cooling options based on renewable energy should be viewed as the most desirable. Deep lakewater cooling falls into this category. There are a variety of other possibilities however. Arguably, if Ontario's energy efficiency improved to the point that existing hydraulic was sufficient, we would have no reason to reject electrical supply. Wind, solar, and biomass are contending electrically energy supply options. Perhaps a more economic option is to use solar thermal collectors to power absorption chillers, with space and water heating supplied by the same collectors. One final example exploits a Canadian resource, once a major export - winter ice. In large scale, seasonal storage of winter freezing could be used for year-round cooling.

Setting aside renewable-based electrical supply options which are beyond the scope of this paper, it is worthwhile expanding on the last two options. Solar thermal cooling has been in use for many years in the U.S. and commercially available products exist albeit hard to come by in Canada. The more fully solar collectors are used (and cooling load matches solar availability quite nicely), the more rapidly their costs are amortized. Even residential hot water heaters can deliver energy at just over $0.01/kWh. Therefore, there would seem to be good reason to gain more experience with this technology.

The seasonal ice making option also deserves further scrutiny. Modest scale pilot projects and paper studies have established feasability. In some applications, heat pumps could draw from ice storage for winter heating. It is also conceivable to deliver district cooling from central ice storage in a similar fashion to DLWC. The economic comparison, then, is between the ice storage facility and a pipeline to the lake depths.

Recommendations

1. Full exploitation of cooling load reduction should be undertaken regardless of the availability of DLWC or other supply options. Retrofit technical potential is typically 75% reduction.

2. Analysis and demonstration of the alternatives discussed in this paper should be carried out regardless of the DLWC development.

3. Radically new approaches to downtown development, HVAC and building design, and the provision of comfort conditions should be pursued.

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MAY 24 1991

Refer to: **Mr. R.G. Ferguson** *File no:* **1163.300** *Date:* **May 23, 1991**

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DEEP LAKE WATER COOLING, METROPOLITAN STRATEGIC PLAN AND MUNICIPAL WATER SUPPLY

Enclosed is a brief report as requested in your letter of April 3, 1991. The report deals with the possible joint use of Deep Lake Water Cooling as a source for the municipal water supply system and briefly addresses Strategic Goals.

If you have any questions, please contact Mr. J.A. Carnduff, P.Eng., Director of Water Supply, at 392-8220.

R.G. Ferguson, P. Eng.
Commissioner of Works

ADT/KTL/cgm 9105504

Encl.

DEEP LAKE WATER COOLING, METROPOLITAN TORONTO
STRATEGIC PLAN AND MUNICIPAL WATER SUPPLY

1. Introduction

The Metropolitan Toronto Works Department has considered the Deep Lake Cooling Water Concept in relation to Works Department activities and responsibilities.

This brief report sets out some of the advantages and disadvantages of the potential use of the Deep Lake Water Cooling project for supplying water to one or more filtration plants. It also addresses briefly the relevance of this project to the broader environmental issues covered in Metropolitan Toronto's Strategic Plan.

The Metropolitan Toronto Strategic Plan has a primary goal of sustainable urban development. Key environmental objectives of the plan and this project's relevance to them include the following:

"To maintain an environmental standard that sustains the natural processes of the region's ecosystem and that benefits the health of current and future generations."

"To reduce the consumption of water, energy and non-renewable resources, and to reduce emissions of gases that are thinning the ozone layer and contributing to global warming."

Fossil fuel is used in Lakeview Generating Station to supply some of the electrical energy to cool core area high density buildings. This results in the emission of CO_2 and other gases as well as waste heat in cooling water. Ontario Hydro faces a potentially limited generating capacity to meet projected growth in future power requirements. Deep Lake Water Cooling may potentially replace electrical energy for the significant cooling load and reduce air emissions, waste heat generation and peak generating capacity expansion requirements.

Studies have indicated that cold lake water from the depths of Lake Ontario is a renewable resource that is replaced annually by cold water that sinks from the surface. The relative quantity of cold water required for cooling seasonally has been estimated to be negligible relative to the total quantity of cold water at depth in Lake Ontario. The application of cold lake water can significantly reduce the use of non-renewable resources of coal and natural gas used in the generation of electricity to power cooling systems. Existing cooling systems exchange heat to outside air and raise the ambient air temperature in the core area of Toronto and this in turn transfers some heat to the adjacent waters of Lake Ontario. Generating Stations which produce electrical power used in existing cooling systems, already send waste heat to Lake Ontario. A future study should determine if, on balance, Deep Lake Water Cooling would send less heat to Lake Ontario than the heat that is now produced by power plants to generate electricity to cool the core area.

There is a concensus that Chlorofluorocarbons (CFC's) cause depletion of the ozone layer which is essential to filter the harmful ultra violet rays of the sun. This filtering is necessary to sustain plant and animal life on the earth. Federal, Provincial and Municipal laws and regulations require the phasing out of CFC compounds for cooling systems over the next few years. This is an appropriate time to consider deep lake water cooling as an alternative cooling source for the alteration or replacement of existing cooling systems.

The deep lake cooling network of supply and exhaust piping has potential to serve as a heating system. District heating plants using best available technology are more efficient than individual building heating systems according to study reports. We understand Ontario Hydro is considering a proposal to bring the Hearn Generating Station on line by the mid 1990's if future forecasts predict increased peak power demand. There is potential to recover the substantial waste heat from this power plant for distribution to the core area thus reducing the non-renewable energy resources now consumed to heat individual core area buildings. This has the potential to reduce CO_2 emissions in Metropolitan Toronto significantly. We suggest to Hydro that further study should be undertaken into the recovery of waste heat from electrical generating plants.

2. Metro's Filtration Plants

The Municipality of Metropolitan Toronto operates four filtration plants as follows:

Filtration Plant	Nominal Capacity Megalitres per Day	INTAKE LOCATION	
		Depth Metres	Offshore Lengths Metres
R.C. Harris	1,000	15.0	2,650 (two intakes)
R.L. Clark	659	18.0	1,615
F.J. Horgan	455	18.0	2,960
Island	273	6.5 15.0	762 (one intake) 762 (second intake)
	2,387		

The existing intakes are considered long enough and deep enough to produce water meeting and exceeding the requirements of the Ontario Drinking Water Objectives using the current treatment processes. A longer intake at a greater depth in the lake may provide more protection from possible future pollution, including biological pollution such as zebra mussels.

3. Options for Water Supply

One of the options is to use the water after it has been circulated through the Deep Lake Water Cooling system and before it is discharged into the harbour. This option is not practical due to the increase in temperature and the concern of maintaining drinking water quality through private systems beyond public control. The idea of using cooling water for drinking purposes would likely not be supported by the Ministry of the Environment under the Ontario Water Resources Act.

Another option to be investigated is the withdrawal of some of the water before it is pumped into the Deep Lake Water Cooling system as raw water for the Island Filtration Plant.

A third option is to construct a shoreline conduit to supply also each of the three filtration plants on the mainland from the 80 metres depth in Lake Ontario offshore from the Toronto Island.

4. Advantages and Disadvantages of Deep Lake Water Cooling

4.1 Advantages

1) According to limited data collected in the Offshore Water Quality Surveillance Program of the Inland Waters Directorate of Environment Canada, the quality of raw water obtained from great depths may be better. However this must be verified by an extensive sampling program.

2) The changes in water temperature affect the control parameters for the drinking water treatment process which need to be adjusted accordingly. The supply of raw water throughout the year at a constant, low temperature of 4°C, may be beneficial to the treatment process,

3) A shoreline utilidor with three separate compartments may have the potential to serve several functions in addition to an alternative water supply source such as storm water tunnel, heating water collection and distribution, and cooling water distribution. However this option would be very capital intensive initially. Also the water supply conduit would have to be free standing within the main conduit and not in contact with the other flows in order to provide access for inspection maintenance and repair.

4) The project has the potential to reduce CO_2 emissions significantly in Metropolitan Toronto by recovering waste heat from fossil fuelled power plants or more probably by expanding the existing district heating network and reducing the number of less efficient individual building heating systems.

5) If the quality of nearshore Lake Ontario water should deteriorate that would support further consideration of a Deep Lake Source for cleaner water supply.

6) The use of Deep Lake Water Cooling system as a source of water supply may be feasible only for the Island Filtration Plant which supplies 12 per cent of Metro's water seasonally during the summer months only. Supply to the Island Filtration Plant would require an additional 10 per cent of the total capacity of the Deep Lake Water Cooling pipe. The feasible application of the Deep Lake Water Cooling to Metro Water Supply appears to be limited to the Island plant. Metro could consider contributing to the additional cost of the incremental increase in capacity to provide a new intake for the Island plant from further offshore.

7) At present, the total discharges into the Toronto Harbour Waterfront from all existing sources amount to 3,350 Megalitres per day in dry weather ("Toronto Waterfront Dry Weather outfall, WPCP and WFP Study, 1988/89 - Summary Report" by Beak Consultants Limited). The outfall from the Deep Lake Water Cooling project would constitute a significant increase (88%) in the total discharges to the Waterfront but the quality may potentially be better resulting in an improvement to Harbour Water Quality. This could benefit beaches on the Harbour side of the Toronto Island Park, as well as other recreational activity in the harbour.

4.2 Disadvantages

1) Deep Lake Water Cooling requires the supply of some 2,940 Megalitres per day (34 m^3/sec). By comparison, the total nominal capacity of all Metro's plants is 2,387 Megalitres per day or over 80 per cent of the proposed requirement for Deep Lake Water Cooling. As a deep lake water supply source, the size of the Deep Lake Water Cooling intake will have to be increased proportionately with consequent increase in the construction costs. However, the capacity can be increased for a fraction of the original cost.

2) The supply of Deep Lake Water Cooling water to R.C. Harris, F.J. Horgan and R.L. Clark Plants will require construction of a new conduit along the water front. The cost of construction of such a conduit may be more than the cost involved in extending/modifying the existing intakes for those plants to the 80 metres depth contour. This contour is a considerable distance offshore of all but the Island Plant. Existing data on the improvement of raw water quality alone would not support the need for a shoreline conduit, however, there may be offsetting benefits of a multi use conduit or utilidor which would be reflected in an overall cost benefit analysis. See appendix 1, Figure 1.

3) The existence of two water distribution systems (one for drinking water and the other for Deep Lake Water Cooling circulation) in commercial or residential buildings gives rise to the possibilities of cross-connections. Such cross-connections may be difficult to identify unless standardization of pipe materials or other method is used to facilitate identification.

4) The Deep Lake Water Cooling report suggests that no chemical of any kind need to be added to the lakewater. However, it must be recognized that all natural waters contain dissolved minerals including the nutrients which sustain microbiological life. Under normal operating conditions, this can lead to the growth of deposits that reduce the cooling efficiency resulting in increased operating and maintenance costs. Such deposits could periodically slough off in the Deep Lake Water Cooling system and could impair its performance.

   On the other hand, if water treatment is used for the Deep Lake Water Cooling water, the cost of such treatment must be considered and the possible impact it would have upon discharge to the receiving water.

5. Recommendations

1) Before the use of any source of water is considered for drinking water supply, extensive raw water quality data must be collected and analyzed. It is recommended that a sampling program at the proposed site(s) for the intake be undertaken to confirm the constant water quality and temperature before the use of Deep Lake Water Cooling water for drinking water supply can be considered further.

2) The possible need for treatment of Deep Lake Water Cooling water should be investigated.

3) Water supply only to the Island Plant only should be considered in greater detail at this time.

4) A comprehensive, broad-based and full environmental cost benefit analysis should be undertaken.

5) Participation of a sufficient number of building owners should be guaranteed by some legislative or other mechanism to ensure the Deep Lake Water Cooling is self-sustaining.

6) Ontario Hydro should be requested to consider the use of waste heat from the Hearn Generating Station if it is reactivated.

ADT/KTL/cgm
May 23, 1991

WATER COOLING PROJECT

Preliminary Estimated Costs

Unit cost of 4.27 m (14 ft) diameter tunnel by Engineering Interface = $7000/m excluding engineering, contingencies and taxes.

Intakes to 80m Depth and Interconnection Options	Tunnel Length (m)	Estimated Cost ($ million)
Island	9,000	63
Intake structure		3
TOTAL	9,000	66
1. Single Intake at Island; Include Shoreline Interconnection Between Island and R.L. Clark		
Island - R.L. Clark	14,000	98
Lakeview Heating Water Link	4,000	28
Island - R.C. Harris	11,000	77
R.C. Harris - F.J. Horgan	14,000	98
Sub-total (additional)	43,000	301
TOTAL (including Island tunnel and intake structure)	52,000	367
2. Single Intake At Island; Include Straight Link Between Island and R.L. Clark		
Island - R.L. Clark	11,000	77
Lakeview Heating Water Link	4,000	28
Island - R.C. Harris	11,000	77
R.C. Harris - F.J. Horgan	14,000	98
Sub-total (additional)	43,000	280
TOTAL (including Island tunnel and intake structure)	52,000	346
3. Three Additional Intakes and Tunnels; No Interconnection		
R.L. Clark	12,000	84
R.C. Harris	6,500	45.5
F.J. Horgan	9,500	66.5
three additional intakes		9
Sub-total (additional)	28,000	205
TOTAL (including Island tunnel and intake structure)	37,000	271

Joint Use Potential (not costed above)

1) Water Cooling
2) Water Heating (Lakeview, Hearn (95))
3) Water supply alternate source (zebra mussel, frazzle ice, quality)
4) storm flow (Beaches, waterfront)

Note: 4.27 m tunnel proposed by Engineering Interface appears to have no backup tunnel. Without backup, cooling source could be lost for several weeks in the event of emergency repairs being required. If a backup dual tunnel were provided for cooling, the backup tunnel could serve also as a water supply backup during summer months when zebra mussel and water quality problems may be greatest. (Back up tunnel not costed above)

Tunnel could be built with larger diameter and compartmentalized for applications 3 and 4 above.

Water Quality Branch - Ontario Region
Inland Waters Directorate
Environment Canada
P.O. Box 5050
867 Lakeshore Rd.
Burlington, Ontario
L7R 4A6

416-336-4963

MAR 11 1991

Votre référence

Notre référence

March 5, 1990

Mr. Bob Tamblyn
Engineering Interface Limited
2 Sheppard Ave East Suite 200
North York, Ont., M2N 5Y7

Dear Mr. Tamblyn;

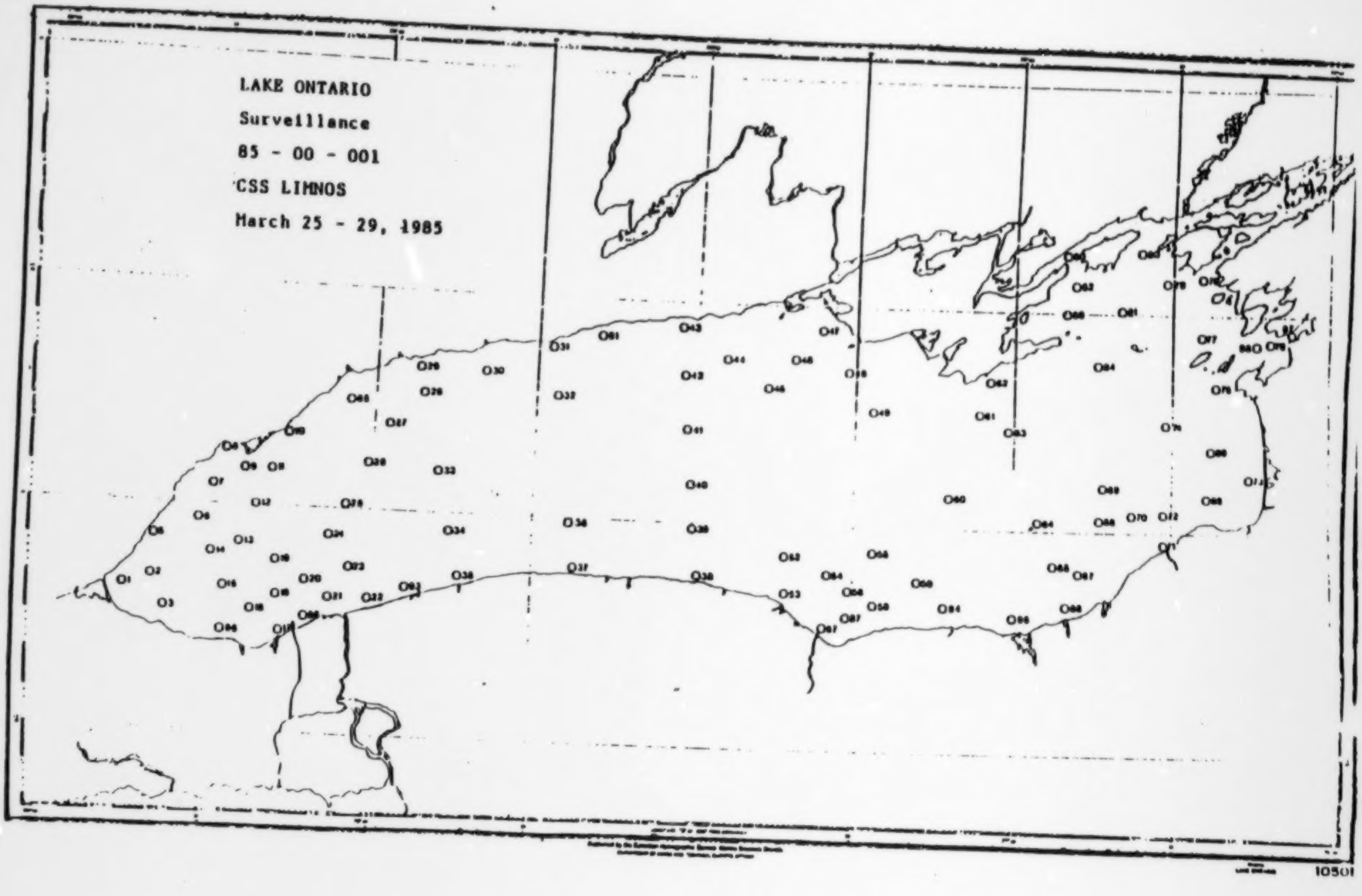
Please find enclosed the water quality data which you requested for the Lake Ontario cruises off Toronto Harbour. I have included data for all parameters from all of our surveillance cruises from 1988 to 1990. Lists of the parameters along with their abbreviations and units are included. A map indicating the station locations is also provided. Please reference this data as: Water Quality Branch - Ontario Region, Inland Waters Directorate, Environment Canada, Unpublished data,1990. I hope that this information will be suitable for your needs. If you have any questions, do not hesitate to call.

Sincerely,

Melanie Neilson

Melanie Neilson
Head Great Lakes Water Quality Division

Canadä



LAKE ONTARIO
Surveillance
85 - 00 - 001
CSS LIMNOS
March 25 - 29, 1985

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2
3
7
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21
30
31
32
34
37
53
70
77
10501

STAR CODES DICTIONARY

ABBREVIATION	DESCRIPTION	UNITS
TEMP	TEMPERATURE (OF WATER)	DEGREES C
SECCHI	SECCHI DISC DEPTH	METRE
FOREL-UL	SECCHI DISC COLOUR	FOREL-ULE SCALE
* TRANS	TRANSPARENCY	PERCENT
T EBT	TEMPERATURE EBT	DEGREES C
D-O2-W	OXYGEN, CONCENTRATION DISSOLVED	MG O2/L
SAT O2	OXYGEN,% SAT. DISSOLVED	PERCENT
PH	PH	PH UNITS
PH TEMP	TEMPERATURE AT WHICH PH WAS TAKEN	CENTIGRADE
SP-CON	SPECIFIC CONDUCTANCE 25 DEG.C	MICROSIEMENS
K FS	POTASSIUM,FIL. PHOTOMETRIC-INTEGRATED	PPM
NA FS	SODIUM,FIL. PHOTOMETRIC-INTEGRATED	PPM
F RES	RESIDUE,FILTRABLE	MG/L
MG F	MAGNESIUM,FILTERED	PPM
CA FA	CALCIUM,FILTERED ATOMIC ABS	PPM
T P	PHOSPHOROUS,TOTAL	MG P/L
TF P	PHOSPHOROUS, TOTAL FILTERED	MG P/L
D ORG C	CARBON, DISSOLVED ORGANIC	MG C/L

* FIRST DIGIT = INSTRUMENT TYPE
SECOND DIGIT = PATH LENGTH
THIRD DIGIT = FILTER COLOUR
LAST TWO DIGITS = %

F FIXR	RESIDUE, FILTRABLE FIXED	MG/L
SO4 F	SULPHATE, FILTERED	MG SO4/L
T KJN NF	TOTAL KJELDAHL NITROGEN UNFILTERED	MG N/L
F ALKCO3	ALKALINITY, FIL. I.R.	MG CACO3/L
CL F	CHLORIDE, FILTERED	MG CL/L
R SIO2	SILICA, SOLUBLE REACTIVE	MG SIO2/L
NH3	AMMONIA NITROGEN, SOLUBLE	MG N/L
NO3NO2 F	NITRATE+NITRITE NITROGEN, FILTERED	MG N/L
SR P	PHOSPHOROUS, SOLUBLE REACTIVE, FILTERED	MG P/L
CACI	CHLOROPHYLL A CORRECTED INTEGRATED	UG/L
CAUI	CHLOROPHYLL A UNCORRECTED INTEGRATED	UG/L
I-N TP	NITROGEN, TOTAL PARTICULATE-INTEGRATED	MG N/L
I-POC	CARBON, PARTICULATE ORGANIC, INTEGRATED	MG C/L

```
                         CCIW WATER QUALITY MONITORING PROGRAM
                        ***************************************
RUISE NUMBER   88-22-030
ESSEL NAME CSS LIMNOS                                   LAKE ONTARIO
                                                        STARTING DATE 15/08/1988

C-REF-NO 030            LAT    43-35-04N
ONS. NO 091             LON   079-19-34W         YEAR 1988          NO. DEPTHS 13
OUNTRY    18            WIND DIR      45         MONTH   08         SOUNDING   92.0
NSTITUTE 22             WIND SP    11 KT         DAY     19         BT TYPE    ELEC
AIR TEMP 13.5                                    TIME 1207          PERM.STA.NO.011

ATHYTHERMOGRAPH:

                  DEPTH     .0    2.0    6.0   14.0   20.0   21.0   38.0   92.0
                  TEMP.   12.4   12.3   10.2    7.0    6.5    5.8    4.0    3.9

EPTH      TEMP       SECCHI      FOREL-UL   TRANS     T EBT     D-O2-W     SAT O2
   .0     12.40        3.5         14.      4070.       --        --         --
  1.0      --          --          --        --       12.09     10.33       97.
  4.0      --          --          --       4070.       --        --         --
 10.5      --          --          --        --        8.01     10.30       88.
 15.0      --          --          --       4080.       --        --         --
 20.0      --          --          --        --         --        --         --
 36.0      --          --          --        --        3.83     12.42       95.
 40.0      --          --          --       4086.       --        --         --
 78.0      --          --          --       4087.       --        --         --
 82.0      --          --          --        --        3.70     12.98       99.
 86.0      --          --          --       4085.       --        --         --
 90.0      --          --          --       4063.      3.67     13.43      102.
 92.0      --          --          --       4062.       --        --         --

EPTH      PH        PH TEMP    SP-CON     R SIO2     CL F      TF P       T P
   .0      --         --         --         --         --        --         --
  1.0     7.86       12.5       310.       .160       21.7     .0046      .0118
  4.0      --         --         --         --         --        --         --
 10.5     7.71        9.3       314.       .230       22.5     .0034      .0092
 15.0      --         --         --         --         --        --         --
 20.0      --         --         --         --         --        --         --
 36.0     7.69        4.9       307.       .420       22.8     .0024      .0056
 40.0      --         --         --         --         --        --         --
 78.0      --         --         --         --         --        --         --
 82.0     7.75        4.4       308.       .540       22.7     .0081      .0037
 86.0      --         --         --         --         --        --         --
 90.0     7.70        4.6       308.       .720       23.6     .0083      .0115
 92.0      --         --         --         --         --        --         --

DEPTH     T KJN NF CACI         CAUI        I-N TP     I-POC
   .0      --      --            --           --         --
  1.0     .200     --            --           --         --
  4.0      --      --            --           --         --
 10.5     .209     --            --           --         --
 15.0      --      --            --           --         --
 20.0      --      --            --           --         --
 36.0     .155     1.0           1.9         .024       .266
 40.0      --      --            --           --         --
 78.0      --      --            --           --         --
 82.0     .149     --            --           --         --
 86.0      --      --            --           --         --
 90.0     .161     --            --           --         --
 92.0      --      --            --           --         --
```

```
                    CCIW WATER QUALITY MONITORING PROGRAM
                   ****************************************
JISE NUMBER  89-22-001
SSEL NAME CSS LIMNOS                                   LAKE ONTARIO
                                                       STARTING DATE 03/04/1989

REF-NO 001          LAT     43-34-59N      YEAR 1989         NO. DEPTHS  7
NS. NO 093          LON    079-13-44W      MONTH   04        SOUNDING    90.0
JNTRY   18          WIND DIR      280      DAY     06        BT TYPE     ELEC
STITUTE 22          WIND SP     13 KT      TIME 2205         PERM.STA.NO.011
R TEMP 4.2

THYTHERMOGRAPH:

            DEPTH     .0   90.0
            TEMP.    2.5    2.5

'TH     TEMP       SECCHI     FOREL-UL TRANS      T EBT      D-O2-W     SAT O2
  .0     2.50        6.5          9.   4081.       --         --         --
 1.0     --          --          --    4081.      2.38      14.66       103.
:0.0     --          --          --     --         --         --         --
'4.0     --          --          --    4081.       --         --         --
'0.0     --          --          --    4083.       --         --         --
17.0     --          --          --    4083.       --         --         --
'0.0     --          --          --    4080.       --         --         --

TH      PH         PH TEMP    F ALKCO3 NH3        NO3NO2 F SR P         CA FA
  .0     --          --         --      --          --       --          --
 1.0    8.11         3.2       94.3    .003        .350     .0014       37.4  —
 0.0     --          --         --      --          --       --          --
 4.0     --          --         --      --          --       --          --
 C.0     --          --         --      --          --       --          --
 7.0     --          --         --      --          --       --          --
 0.0     --          --         --      --          --       --          --

TH      SO4 F      R SIO2     CL F     T KJN NF TF P       T P          CACI
  .0     --          --        --        --       --         --          --
 1.0    27.4        .460      22.9      .169     .C042      .C102        --
 0.0     --          --        --        --       --         --          3.2
 4.0     --          --        --        --       --         --          --
 0.0     --          --        --        --       --         --          --
 7.0     --          --        --        --       --         --          --
 0.0     --          --        --        --       --         --          --

TH      CAUI       I-N TP     I-POC
  .0     --          --        --
 1.0     --          --        --
 C.0     4.2        .045      .270
 4.0     --          --        --
 0.0     --          --        --
 7.0     --          --        --
 0.0     --          --        --
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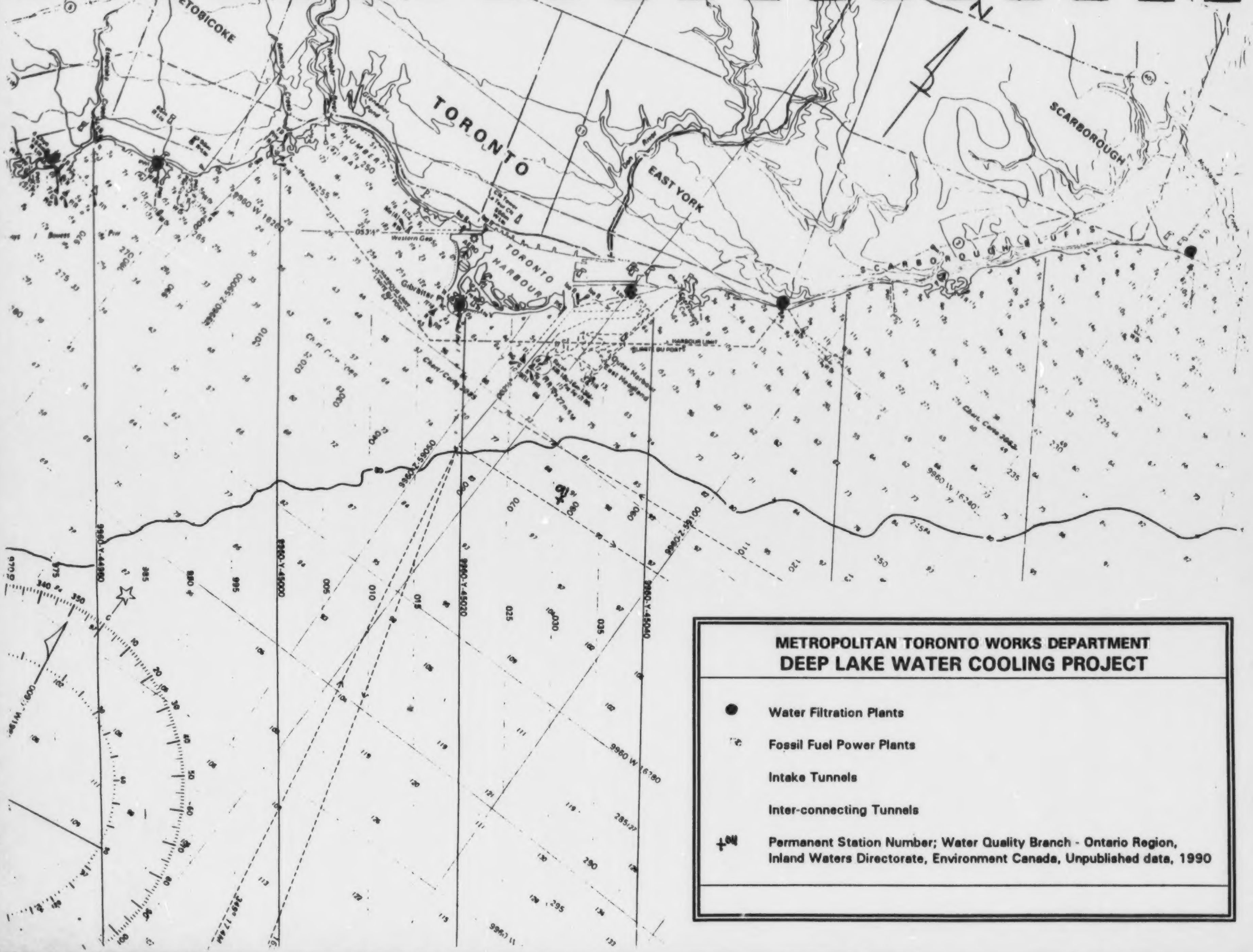
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ETOBICOKE
TORONTO
EAST YORK
SCARBOROUGH
TORONTO HARBOUR
HUMBER BAY
SCARBOROUGH BLUFFS
Gibraltar Pt.
Western Gap
9960-Y-44980
9960-Y-45000
9960-Y-45020
9960-Y-45040
9960 W 16280
9960-Z-59050
9960-Z-59100
9960-Z-59000
9960 W 16240
Chart Carte 2062

METROPOLITAN TORONTO WORKS DEPARTMENT

DEEP LAKE WATER COOLING PROJECT

- ● Water Filtration Plants
- Fossil Fuel Power Plants
- Intake Tunnels
- Inter-connecting Tunnels
- Permanent Station Number; Water Quality Branch - Ontario Region, Inland Waters Directorate, Environment Canada, Unpublished data, 1990

City of Toronto
Department of Public Works
and the Environment

Nioholas Vardin, P.Eng.,
City Engineer and Commissioner

City Hall, Toronto, Ontario M5H 2N2
Fax: 392-0816

Reply Attention: W. Wichmann

Dial Direct: 392-7674

May 15, 1991.

Traffic Impact - Installation of
Freecool System in the Downtown Area.

HAND DELIVERED

RECEIVED
MAY 15 1991

Mr. Richard Gilbert,
President,
Canadian Urban Institute,
2nd Floor, West Tower,
City Hall.

Dear Mr. Gilbert:

I am pleased to enclose, as requested, a brief paper on the impact of constructing a Freecool grid on the traffic in the downtown area.

Yours truly,

Commissioner.

DJ
WW

Attachment

May 15, 1991.

CITY OF TORONTO
DEPARTMENT OF PUBLIC WORKS AND THE ENVIRONMENT
NICHOLAS VARDIN, P.ENG., COMMISSIONER AND CITY ENGINEER

IMPACT OF INSTALLATION OF A FREECOOL PIPE GRID ON THE TRAFFIC IN THE TORONTO DOWNTOWN AREA

The proposed Freecool Grid is to be installed in the downtown area of the City which is extremely congested by vehicular traffic above surface and by underground utilities below surface.

The impact of the construction of the pipe system on downtown traffic depends on construction techniques and construction management with respect to shaft locations, staging areas, transportation routes for spoil disposal, and working areas.

Because of underground utilities and traffic conditions, it is anticipated that the majority of the freecool pipe grid would be constructed in tunnel.

For the larger, suitable for person entry type pipes (1.5 metre diameter and greater), it can be expected that conventional tunnelling machines will be utilized. A main construction area and shaft to lower the tunnel machines will be required in the vicinity of Queens Quay. The construction site and shaft at this location should ideally be located on property outside the travelled road allowance. The property could be leased or purchased, and could also be utilized as the location for the pumping station required for the Freecool System. From this location, tunnelling could proceed in three directions concurrently: South - East/North - West/North. From the Queens Quay shaft, it may be possible to tunnel all the way north to Charles Street or Bloor Street, where the tunnelling machine would have to be removed. However, that would require a uniform pipe size between Queens Quay and Bloor Street and the widening of the tunnel at one location in the vicinity of Dundas Street to allow the passing of trains for the removal of excavation material.

Alternatively, intermittent access shafts could be constructed approximately halfway between Bloor Street West and Queens Quay on a minor intersecting cross street, e.g. Elm Street. This would allow the removal of excavation material and the exchange of the tunnelling machine if a smaller pipe diameter in the northern section of the trunk mains is proposed. Such construction shaft would require two lanes to be closed during the time when the shaft is being constructed (4 to 6 weeks) and during removal of the machine, and one lane to be closed during removal of excavation material. The shafts located in the vicinity of Bloor Street West would also require the closure of two lanes during construction of the shafts and during removal of the tunnelling machines.

The advantage of just one shaft for lowering the machines and excavation removal at Queens Quay is that no intermittent access shafts would need to be constructed, and that truck traffic, in connection with the removal of excavation material in the downtown area, would be greatly reduced.

For the installation of the smaller pipes not suitable for person entry, microtunnelling technology should be utilized. This method of construction utilizes an articulated remote controlled tunnelling machine and an auger, or a slurry system for the removal of excavation material. The pipes are jacked behind the tunnelling machine. Construction shafts are required approximately every 150 metres. Construction shafts require the permanent closure of one lane during construction. Besides using less space for construction, microtunnelling minimizes the amount of excavation material to be removed and, therefore, reduces truck traffic.

In addition to the pipe installation, the construction of various control chambers, pipe junction structures, and service connections will be necessary. The larger structures could be constructed using underground mining techniques, except for the access shaft rising to the surface which would require the closure of one lane during construction. It is anticipated that the smaller structures would only require the closure of one lane during construction. Night work will be required if a second lane is required for construction purposes or at locations where no lane closure during daytime can be permitted.

The alignment of the trunk mains and the sizing of the pipes should not only be determined on the basis of hydraulics but should take into account the feasibility of construction and the impact of construction sites and shafts on traffic and underground utilities. For example, it may be preferable to relocate the proposed Yonge Street trunk main to Church Street. In this respect, a feasibility study for the location of construction shafts should be conducted.

In summary, the construction of the freecool grid can be accomplished by closing one lane of traffic for the installation of underground chambers and for construction shafts, except for the shafts required for lowering and removing the tunnelling machines for the large pipes which will require the closure of two lanes. In addition, night work and weekend work, with the excavation plated during daytime, could be specified to further reduce lane closures and adverse impact on traffic. Night and weekend work only may be required on all arterial roads. The closure of one lane of traffic on minor streets is not expected to cause undue traffic congestion and could be permitted.

If the construction work will be carried out as indicated above, the impact on traffic in the downtown area during the working days would be small.

Commissioner.

RECEIVED
MAY 13 1991

City of Toronto
Department of Public Works
and the Environment

Nicholas Vardin, P.Eng.,
City Engineer and Commissioner

City Hall, Toronto, Ontario M5H 2N2
Fax: 392-0816

Reply Attention: K. Hemmerich

Dial Direct: 392-7763

May 13, 1991.

Freecool/Central Air-
Conditioning - Noise
Ramifications.

Mr. Richard Gilbert,
President,
Canadian Urban Institute,
2nd Floor, West Tower,
City Hall.

Dear Mr. Gilbert:

As per the request of the Steering Committee regarding the above, I am pleased to note the following information.

My records show that for the past 5 years there have been approximately 25 complaints due to noise from larger air-conditioning systems in commercial or large residential complexes. Of these, the majority were locations in the core area, i.e. within the proposed grid system for Freecool. In most cases, the machinery (compressors, fans, etc.) is located on rooftops.

Generally, the sound output of this machinery is at a level that would cause a disturbance to a receiver within a short distance if no effective attenuation measures are provided at source or the point of receiver.

The majority of the above complaints resulted from the installation of new machinery close to existing residential uses or from constructing a residential building close to existing machinery. Generally, retrofitting the machinery with adequate attenuation measures, enforced under the provisions of the Noise By-law, resolve the noise problem.

Address all correspondence to the Commissioner

Printed on post-consumer recycled paper

The more problematic situations are noise sources due to a large number of individual window or through-the-wall air-conditioning units. There are no practical attenuation measures available for this condition which is often the preferred solution in assisted housing projects to minimize up-front cost. Particularly in these cases, Freecool would be quite beneficial in eliminating noise sources.

In view of the recognized need for more affordable housing in the central area, Freecool has the potential for reducing increasing noise problems.

Although, as stated above, the number of acute noise problems in the core area due to machinery of centralized air-conditioning systems is limited, a large number of these systems contributing to the ambient noise level could be eliminated by the Freecool concept. It should be noted, however, that a reduction of the ambient noise level makes other noise sources more predominant. While currently masked by a higher ambient noise level, other sources such as traffic noise might become a disturbing noise source once the ambient noise level has been reduced.

Should you have any further questions, please contact Mr. K. Hemmerich at 392-7763.

Yours truly,

Commissioner.

_____sh
KH

MAY 27 1991

City of Toronto
Department of Public Health

P.R.W. Kendall, MBBS, MSc, FRCPC
Medical Officer of Health

Reply Attention

Telephone

May 27, 1991

Mr. Nicholas Vardin
Commissioner
Department of Public Works and the Environment
23rd Floor, East Tower
City Hall
Toronto, Ontario
M5H 2N2

Dear Mr. Vardin:

Re: Environmental and Health Impacts Associated with Cooling Towers

I have asked staff at the Environmental Protection Office (EPO) to conduct some research into the above issue. Given the limited time, a comprehensive review was not possible. Therefore, I would consider this information to be preliminary in nature, identifying only areas of concern for future, more in depth investigation.

I have attached three articles that describe the microbicides and corrosion inhibiting chemicals used in cooling towers. These articles provide some general chemical information, describe briefly their method of action, and trace the evolution of these chemicals toward less environmentally damaging alternatives.

It is important to note that two of these articles have been written by a company that markets these chemicals, while the author of the third article is unknown. My staff did not have sufficient time to verify the statements made in these articles, or to identify contrary points of view. I would suggest that this information be used only as a starting point for further investigation.

There are apparently many different possible blends of microbicides and corrosion inhibitors depending upon the type of cooling tower and the needs of the user. Company officials

☐ Office of M.O.H.
City Hall, 7th Floor, East Tower
Toronto, Ontario M5H 2N2
Fax: 392-0713

☐ Central Resources
City Hall, 7th Floor, East Tower
Toronto, Ontario M5H 2N2
Fax: 392-0713

☐ Downtown Health Area
City Hall, 6th Floor, East Tower
Toronto, Ontario M5H 2N2
Fax: 392-0713

☐ Eastern Health Area
815 Danforth Ave., 2nd Fl
Toronto, Ontario M4J 1L2
Fax: 392-0714

☐ Northern Health Area
188 Eglinton Ave. E., 5th Fl
Toronto, Ontario M4P 2X7
Fax: 392-0716

☐ Western Health Area
2340 Dundas Street West
Toronto, Ontario M6P 4A9
Fax: 392-0715

City of Toronto Health Unit

were reluctant to supply specific information on these chemicals on short notice for proprietary reasons. This information could be obtained by written request, but sufficient time was not available.

According to officials at two major chemical distributors (Dearborn Chemicals and Specialty Chemicals), all of the microbicides have received approval under the Federal Pesticides Act. Microbicides and corrosion inhibitors must also conform to the sewer use by-law of the municipality in which the cooling tower operates.

With regard to your question on Legionnaires' Disease, the association between the Legionella pneumophila bacterium and cooling tower water is strong. However, these bacteria have also been cultured from water obtained from many other sources including taps and natural water bodies. Therefore, although cooling towers may represent a particularly suitable environment for the reproduction of Legionella pneumophila, they can by no means be considered the only source.

In conclusion, I must emphasize the preliminary nature of this work. The attached articles are provided as a starting point and may not be representative of the literature. If you wish to discuss this further, please contact Vic Nishi of the Environmental Protection Office at 392-6788.

Yours truly,

P.R.W. Kendall, MBBS, MSc, FRCPC
Medical Officer of Health

Enclosures

c.c. Ms. Gillian Mason
Canadian Urban Institute

SPECIALTY CHEMICALS
Division of Drew Chemical Limited

EFFECTIVENESS OF ENVIRONMENTALLY ACCEPTABLE WATER TREATMENT CHEMICALS FOR HEATING AND COOLING PLANTS

BY: Ted Beardwood
Technical Director

Specialty CHEMICALS
DIVISION OF
DREW CHEMICAL LIMITED

270 Industrial Parkway, Aurora, Ontario, Canada L4G 3T9

416-773-633

INTRODUCTION

Although the problems that are incurred when water is used as a heat transfer medium are well entrenched, their existence and the classical overview chemistry describing their development will remain in the future. Chemical mechanisms and chemical additives used to minimize and prevent scale, corrosion, and fouling in aqueous heat transfer systems are areas of future change.

The driving force for the development of new chemistry has been driven by the need for more environmentally acceptable chemicals which can be handled safely. Health and Welfare and Environmental Regulations have aided in the initial design search of new water treatment compounds. Safety of the workplace and the environment in areas of transportation, application, discharge, waste and accidental hazards are paramount. The design and end use application procedures of this chemistry also requires that proper communications and understanding is present between suppliers and users in order to attain the desired water treatment objectives while maintaining good corporate and environmental citizenship.

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CHEMISTRY CRITERIA AND CONCERNS

A. It will no longer suffice to design an additive based soley on resolving a problem. In the design stages many other criterias will also have to be met in order to provide the best available and most acceptable technology.

The additive concentrate may be designed with coupling agents, solvent systems, and pH adjusters. Therefore, it will not be just the active agents that require evaluation but also all ingredients which go into the additive compound to form a stable concentrate. Newly proposed organic inhibitor substitutes and organic water treatment packages will have to provide results equivalent to, or better than the previously used inorganic compounds. "Bench Mark" comparisons are performed between the new and the old technology results in the areas of:

- deposit loading (gram/ft^2) on heat transfer surfaces;
- fouling factors [(hr)(ft^2)(°F)/Btu] on heat transfer surfaces;
- pitting potential;
- underdeposit corrosion potential;
- repassivation potential;
- overall corrosion inhibition.

Figure 1 and 2 outlines the various programs available which have passed static testing. These dynamic tests simulate actual system operations to obtain relative corrosion rates and hence corrosion inhibition ability. Figure 3 outlines corrosion performance tests in aerated and stagnant/deaerated conditions. These results can be improved by either prefilming or addition of an organic compound during aerated conditions prior to shutdown/stagnant conditions. It can also be improved by utilizing organic compounds with prefilming during aeration prior to stagnant conditions. This is due to the fact that inorganics require oxygen while organics are less dependent on oxygen if prefilming has been performed. Figure 4 outlines dynamic testing of scale and fouling performance assessment of the organic compounds.

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Environmentally acceptable programs rely on a much more tighter operational control. The programs have more system water engineering parameters (see Figure 5) to consider, to obtain optimum performance vs the old guard inorganic or heavy metal water treatment packages. The stability index of the water is a function of the following parameters:

1) temperature;
2) total dissolved solids;
3) calcium hardness;
4) total alkalinity;
5) pH.

These parameters as well as carbonate, alkalinity, iron and silica of the water require balancing to engineer the water prior to organic water treatment overlays to provide both scale and corrosion inhibition. After the engineering is completed, then the simplified control parameter product control levels are fixed for the particular water and treatment. This then requires a few extra water tests than normal and in some cases the test(s) is a little more complicated than the probable colour comparison tests previously performed.

Use costs for environmentally acceptable treatments has always been of interest. Such comparisons will only be relative to the present program you intend to replace. If, for example, your present program has utilized 1960 technology (acid/chromate/chlorine) and has not been updated until now due to regulatory conformity desires, then use cost will be significantly more. However, if your treatment programs have been updated to the last advance in technology prior to all-organic programs then the use costs will only slightly (i.e. marginally) be higher. All-organic treatment costs are tied into the cost of oil (both directly and indirectly), require a high degree of energy to produce and are unique in supply (i.e. not commodities) and design. Hence, an overall increase in procurement cost, not to mention the research cost in designing an effective and affordable product blend, which is environmentally acceptable.

B. Another area of concern when designing environmentally acceptable treatments is that of the undiluted concentrate with respect to the individual components and their synergistic effects in the following areas for handling/transporting acceptability, are:

3/....

B. Cont'd.

- environmental biodegradability;
- corrosiveness when in contact with materials of construction and applicators;
- flammability/combustibility/explosive;
- chemical stability of the concentrate, reactivity with other chemicals and by-products produced;
- potential incompatibility with other substances/compounds and by-products produced;
- food or nutrient sources for microorganisms;
- pressure and/or temperature effects on the compound, decomposition products produced and their effects;
- toxicity to man, animal and aquatic life in the areas of:
    - inhalation - LC_{50} (ppm, mg/m^3)
    - ingestion - oral LD_{50} (mg/kg)
    - adsorption - Dermal LD_{50} (mg/kg)
    - Aquatic Bioassays 96_h LC_{50} (ppm);
- allergic reaction;
- carcinogen;
- effects on fertility (i.e. reproductivity);
- birth deffects;
- mutations of the cell DNA;
- synergistic effects, if any, of the combination of compounds present.

In order to put toxicity into perspective, a criteria listing of LD_{50}, LC_{50} and TLV values and their ratings have been presented in Figure 6, Tables 1 and 2. Figure 7 provides an outline of a few compounds and their corresponding LD_{50} values. It has also been shown that if a 176 lb. man was to drink cooling water containing 10 ppm chromate it would require an uptake of 24.3 times the man's own weight in cooling water without excretion before he had a 50% chance of death from only the chromate present. This is outlined in a worked example contained in Figure 8.

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It is quite possible that the man would become ill long before the full uptake from the decaying vegetation, bird droppings, and other airborne pollutants scrubbed out by the cooling tower operation. Comparisons of various liquid treatments available in the marketplace are made with respect to the LD_{50} values of the concentrate and the treated system water in Figure 9. It can be seen that all concentration are in the slightly to practically non-toxic classification while the majority of them at end use (i.e. in system) treatment levels are classed as relatively harmless. Hence, overall acceptability factors are high in this area.

DISCHARGE AND WASTE PRODUCTION

Now let us turn to the other side of the acceptability issue, that is, the regulatory constraints placed on discharge and waste production by governmental bodies. Regulation 309 was primarily designed to reduce waste production as well as a segregation of waste for proper handling treatment and disposal of said waste. An application to register a waste must be made and approved prior to the discharge or dumping. In short, the guidelines for what actually constitutes a waste in the case of treated water discharge or dumping are:

1) Any discharge to waters under the jurisdiction of a municipality must meet the by-laws in force by the municipality for sanitary (refer to Figure 11) or storm (refer to Figure 12) sewer discharge limits. It is the municipality that is then responsible for treatment and prevention of waste discharge to the environment in exces of the M.O.E. limits. This is diagramatically illustrated in Figure 10 whereby the waste generating process is discharged to a municipality control system as items 2 and 3.

2) Any discharge to waters not under item 1 becomes the direct jurisdiction of the M.O.E. A waste requiring registration is then considered one to have greater than 100 times the concentration of the allowable maximum value for safe drinking water (refer to Figure 14).

For example, consider a cooling water containing 10 ppm chromate as CrO_4 that is to be discharged:

i) 10 ppm chromate as CrO_4 = 4.5 chromium as Cr

ii) safe drinking water limit - 0.05 ppm as Cr
registration required at 0.05 x 100 = 5.0 ppm as Cr

iii) sanitary sewer by-law - less than or equal to 3 ppm as Cr

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From the preceding it can be seen the discharge requires registration as it is above the by-law limits of 3 ppm as Cr if discharged into a sanitary sewer of the governing municipality.

Discharge of waters to municipal sanitary and storm sewers, streams, creeks, rivers and lakes all have maximum limits of allowable impurities. These are present in the accompanying figures as such:

Figure 11 - Municipality of Metro Toronto By-Law for discharge to sanitary sewer.

Figure 12 - Municipality of Metro Toronto By-Law for discharge to storm sewer.

Figure 13 - "Model" By-Law to control liquid waste discharge to municipal sewers.

Figure 14 - Proposed (1984) drinking water quality for maximum acceptable concentration parameters related to health.

Figure 15 - Water quality criteria for livestock watering.

Figure 16 - Recommended maximum concentrations of trace elements in irrigation waters.

Now environmentally acceptable products are those which meet and do not violate environmental discharge values as outlined in Figures 11 through 16 (excluding 13 as it is a model). A summary of the acceptable discharge limit values are made in Figure 17 and the common 8 (i.e. A through H) inhibitory packages available are also presented in this figure as to whether they can be discharged (✓) or not (x) into the various waterways. After scanning this information a number of questions came to mind:

1) If a treatment/system water can be discharged into a natural waterway and considered safe for drinking, irrigation and livestock watering, why then is it not acceptable for storm sewer discharge? (inhibitor package B & E)

2) If a treatment/system water discharge is considered unsafe for drinking then why is it allowed for livestock watering? (inhibitor package D & G)

3) If a treatment/system water discharge is considered safe for drinking and livestock watering, why is it unacceptable for irrigation? (inhibitor package C)

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From these questions of confusion when following the guidelines, one may pose the question of, morally, what is right? Morality is a personal view and the correct choice is not the same between one person to another, one group to another, one nation to another. However, from the standpoint of the water treatment industry, coupled with known toxicity vs governing body guidelines, the following, morally, would be acceptable:

A) Open cooling water treatment discharge to sanitary sewer - choose C, D, or E inhibitor packages.

Discharge to storm sewer or waterway - choose D or E inhibitor packages.

B) Closed system water treatment - choose inhibitor packages G or H and discharge only to sanitory sewers.

To illustrate even further moral issues without producing paranoia, a few examples from the Canadian Cancer Society Bulletin of June 1986 - 211419 on diets, will be itemized herein.

1) Saturated and unsaturated fats contained in visible meat fat, sauces, gravey, butter, oil and mayonnaise will increase bile secretion. This has been linked with increased bacterial productio of carcinogens.

2) Vitamin A or carotene containing foods tend to block cancer production reactions. However, large doses of Vitamin A can cause illness or even death.

3) Nitrite/Nitrate cured or preserved meats will combine with amines and amides (i.e. amino acids and proteins) to form nitrosoamines and nitrosoamides. These are now carcinogens. However, without their use, botulism caused deaths would increase.

4) Vitamin C inhibits the formation of nitrosoamines and nitrosoamides.

5) Smoking causes cancer.

6) Alcohol consumption can lead to liver cancer.

7) Beer drinking can lead to rectal and colon cancer.

8) Salt causes stomach irritation and has been associated with stomach cancer.

9) Vitamin E and B have been linked to cancer production, however, no clear mechanism is present to confirm the relationship.

7/....

10) Large doses of arsenic, cadmium and lead are associated with cancer.

11) Saccharin and cyclamates used as food additives for years are cancer causing agents. They are no longer in use.

12) Antioxidants used in food to prevent fats from going rancid have been linked to cancer. However, no clear relationship is present. Examples are:

    - BHT - Butylated Hydroxytoluene

    - BHA - Butylated Hydroxyanisole

13) Peanut and grain mold produce aflatoxin which is a known carcinogen.

14) Barbecuing, grilling or smoking of meats leads to fat dripping onto hot elements causing flare-ups which produce and deposit benzopyrene onto the food. This substance is a known carcinogen.

Morally, it becomes difficult to determine what and who is spoiling or killing what any more. In fact, some of our own personal habits, diets or needs, not only affect our health but others also. As a further interest, an article on natural toxins is enclosed in the appendix for reading. The major chemical offenders to the environment are actually those used in household cleaners (surfactants), herbacides, pesticides and fungicides. We eventually ingest these agricultural chemicals in one form or another. Will we ever decide what is actually acceptable and make it a common law across the board?

APPENDIX OF FIGURES

FIGURE 1

Program	CORROSION RATES pH = 7.0 - 7.5 (mpy) Mild Steel
Blank	51.6
High Phosphate	2.8
Molybdate/Zinc	5.2
Chromate/Zinc	1.5
All-Organic I	6.0
All-Organic II	3.4

Test Conditions	
Total Hardness (as $CaCO_3$)	400 ppm
Total Alkalinity (as $CaCO_3$)	20 ppm
Chloride (as Cl)	500 ppm
Sulfate (as SO_4)	500 ppm
Temperature	180°F
Flow	2 FPS
RSI	7.30

FIGURE 2

CORROSION RATES (mpy)

pH 7.5 - 8.0

Progam	Mild Steel
Blank	43.2
High phosphate	3.3
Molybdate/zinc	3.5
Chromate/zinc	3.0
All-Organic I	4.0
All-Organic II	2.0

Test Conditions	
Total hardness (as $CaCO_3$)	400 ppm
Total alkalinity (as $CaCO_3$)	170 ppm
Chloride (as Cl)	210 ppm
Sulfate (as SO_4)	95 ppm
Temperature	180°F
Flow	2 FPS
RSI	4.91

FIGURE 3

CORROSION RATES OF CHROMATE/ZINC/PHOSPHONATE

Chromate	10 ppm	50 ppm	100 ppm
Stagnant	0.73 mpy	0.43 mpy	0.40 mpy
Coupon #	1907	1908	1910
Aerated	0.39 mpy	0.10 mpy	0.11 mpy
Coupon #	1906	1909	1911

NOTE:

1) Duration of test was 7 days.
2) Preferred method of prefilming of coupon was not performed.
3) Maximum corrosion occurs during the first 5-10 days.
4) Corrosion rates are only relative to provide a trend as items 1-3 are not the accepted norm for evaluation.

FIGURE 4

Typical Water Analysis

	ppm
Total Hardness (as $CaCO_3$)	520
Calcium (as $CaCO_3$)	340
Chloride (as Cl)	140
Total Dissolved Solids	1260
Total PO_4	14.2
LSI	+1.2
RSI	5.18

Test Conditions

Flow	4 GPM
Btu	4600
Ave. T's	180°F

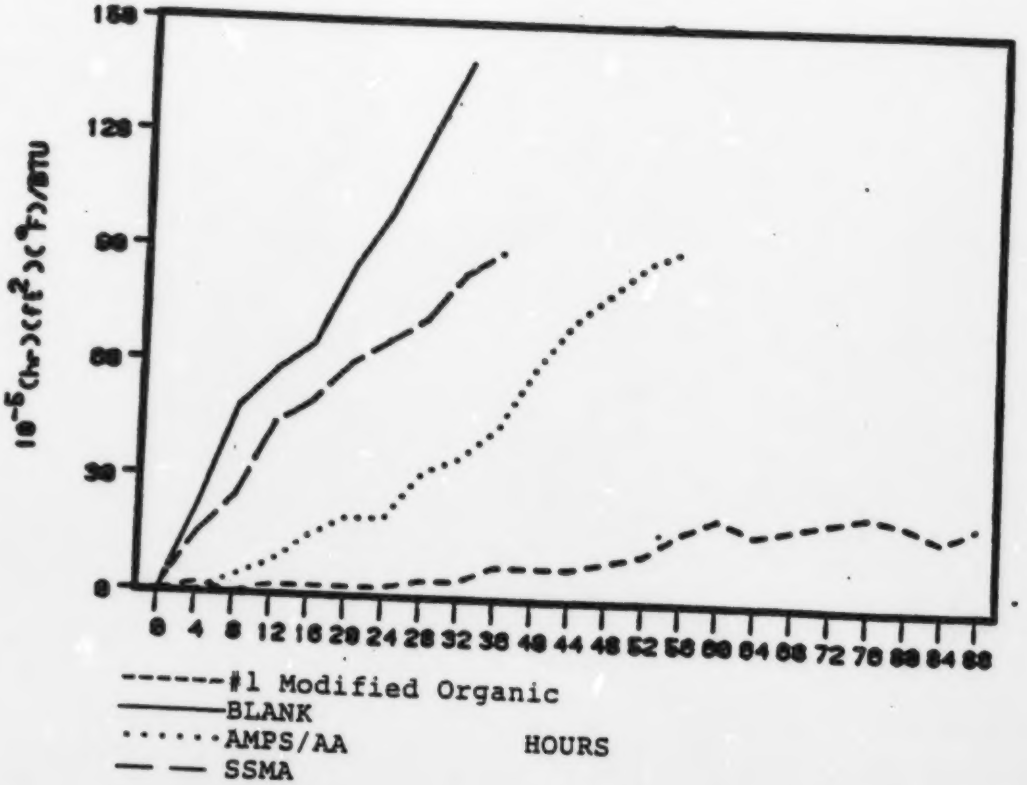


FIGURE 5

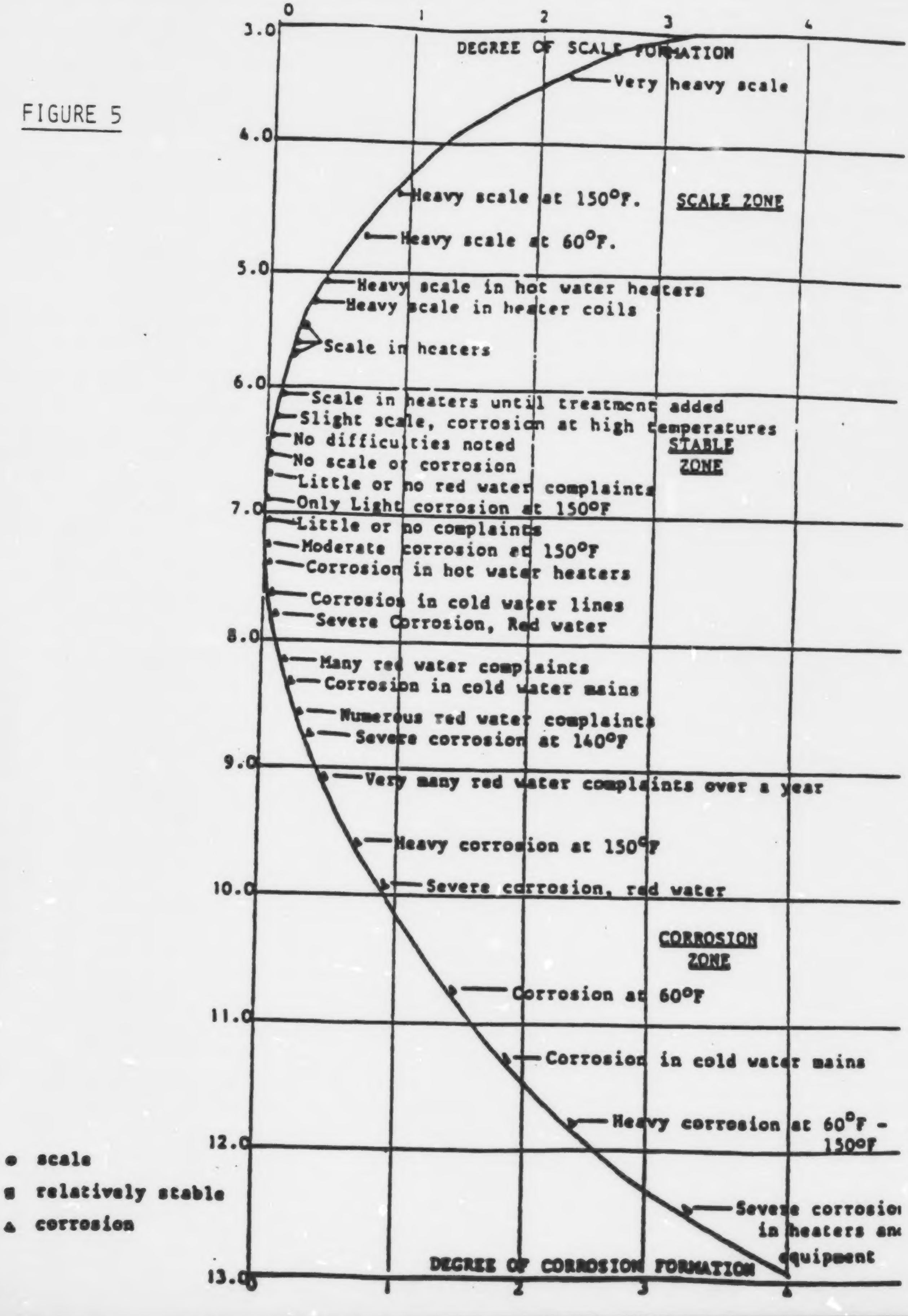

DEGREE OF SCALE FORMATION
0
1
2
3
4
3.0
4.0
5.0
6.0
7.0
8.0
9.0
10.0
11.0
12.0
13.0
Very heavy scale
Heavy scale at 150°F.
SCALE ZONE
Heavy scale at 60°F.
Heavy scale in hot water heaters
Heavy scale in heater coils
Scale in heaters
Scale in heaters until treatment added
Slight scale, corrosion at high temperatures
No difficulties noted
STABLE ZONE
No scale or corrosion
Little or no red water complaints
Only Light corrosion at 150°F
Little or no complaints
Moderate corrosion at 150°F
Corrosion in hot water heaters
Corrosion in cold water lines
Severe Corrosion, Red water
Many red water complaints
Corrosion in cold water mains
Numerous red water complaints
Severe corrosion at 140°F
Very many red water complaints over a year
Heavy corrosion at 150°F
Severe corrosion, red water
CORROSION ZONE
Corrosion at 60°F
Corrosion in cold water mains
Heavy corrosion at 60°F - 150°F
Severe corrosio in heaters an equipment
DEGREE OF CORROSION FORMATION
0
1
2
3
4
● scale
■ relatively stable
▲ corrosion

FIGURE 6

TABLE 1

Relative Toxicity Criteria Based on TLV's

Rating	Commonly Used Term	TLV ppm	TLV mg/c.m.
4	Extremely Toxic	≤10	≤.25
3	Highly Toxic	11 to 250	.26 to 2.5
2	Moderately Toxic	251 to 500	2.51 to 5.0
1	Slightly Toxic or Practically Non-Toxic	501 to 1000	5.1 to 10
0	Relatively Harmless	>1000	>10

TABLE 2

Relative Toxicity Criteria Based on LD_{50} and LC_{50} Data

Commonly Used Term	LD_{50} Single Oral Dose Rats mg/kg	LC_{50} Inhalation 4-hr. Vapor Exposure Rats ppm	LD_{50}-Skin Rabbits mg/kg
Extremely Toxic	≤1	≤10	≤5
Highly Toxic	1.1 to 50	11 to 100	5.1 to 43
Moderately Toxic	50.1 to 500	101 to 1,000	44 to 340
Slightly Toxic or Practically Non-Toxic	501 to 15,000	1,001 to 100,000	350 to 22,600
Relatively Harmless	>15,000	>100,000	>22,600

FIGURE 7

TOXICITY OF SOME COMPOUNDS

COMPOUND	TOXICITY GRADE	TLV mg/m^3	LD_{50} mg/kg
Sodium Hypochlorites (Bleach)	1	N/A	8900
Sodium Silicate	2	N/A	250
Sodium Floride	3	N/A	180
Sodium Sulfite	2	N/A	743
10% Sodium Hydroxide		N/A	500
Sodium Chromate	3	0.1	243
Sodium Nitrite	3	N/A	85
Molybdic Trioxide	3	5	125
Sodium Molybdate	2	N/A	570
Hydrazine Hydrate	3	1 ppm	129
Sodium Cyanide	4	N/A	6.44

[TESTS PERFORMED ON RATS]

TESTS PERFORMED ON RAINBOW TROUT:

	TOXICITY mg/l (TL^{50})
Molybdate	7340
Chromate	285

FIGURE 9

COMPARISON OF LD_{50} VALUES

Type of Liquid Treatment		LD_{50} mg/kg in Drum	LD_{50} mg/kg in System
Chromate/Zinc/Phosphonate	A	1,111	37,033
Zinc/Phosphonate	B	19,210	640,333
Molybdate/Phosphonate	C	24,000	800,000
Chromate/Zinc/Molybdate/ Phosphonate/Polymer	D	5,882	196,066
All-Organic	E	45,000 ⊛	1,500,000
Nitrite/Borate	F	2,125	4,250
Molybdate/Nitrite	G	4,250	8,500
Molybdate	H	98,666	197,332

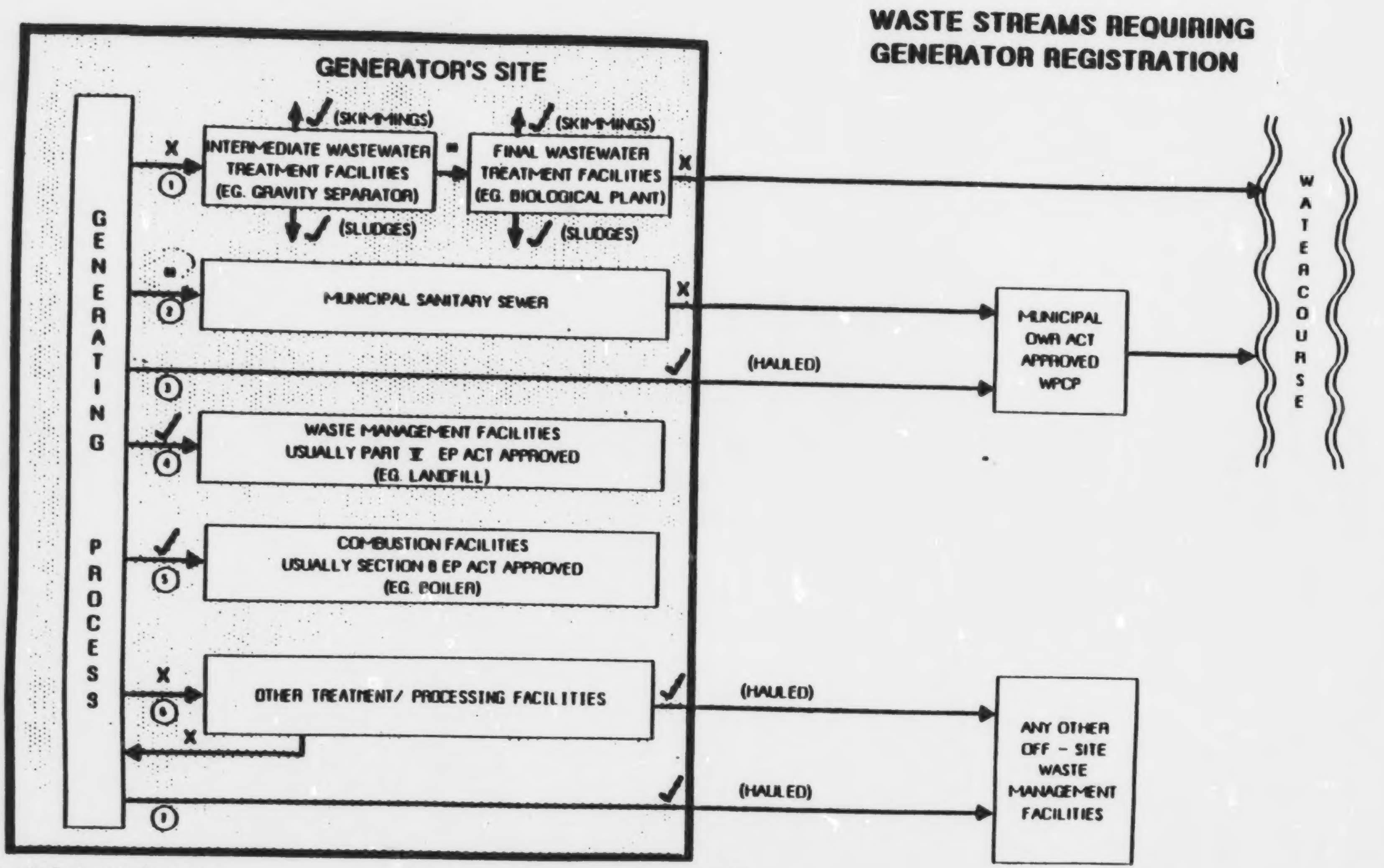
NOTE: LD_{50} values greater than 500 but less than 15,000 are considered slightly or practically non toxic.

LD_{50} values greater than 15,000 are considered relatively harmless.

⊛ LD_{50} based on caustic added to product.

F I G U R E 10

WASTE STREAMS REQUIRING GENERATOR REGISTRATION


GENERATOR'S SITE
GENERATING PROCESS
X
①
INTERMEDIATE WASTEWATER TREATMENT FACILITIES (EG. GRAVITY SEPARATOR)
✓ (SKIMMINGS)
✓ (SLUDGES)
*
FINAL WASTEWATER TREATMENT FACILITIES (EG. BIOLOGICAL PLANT)
✓ (SKIMMINGS)
✓ (SLUDGES)
X
*
②
MUNICIPAL SANITARY SEWER
X
③
✓
(HAULED)
MUNICIPAL OWR ACT APPROVED WPCP
WATERCOURSE
✓
④
WASTE MANAGEMENT FACILITIES USUALLY PART V EP ACT APPROVED (EG. LANDFILL)
✓
⑤
COMBUSTION FACILITIES USUALLY SECTION 8 EP ACT APPROVED (EG. BOILER)
X
⑥
OTHER TREATMENT/ PROCESSING FACILITIES
X
✓
(HAULED)
⑦
✓
(HAULED)
ANY OTHER OFF - SITE WASTE MANAGEMENT FACILITIES

X – No Registration Required

✓ – Hazardous, LIW, & RSW Registration Required

* – Only Hazardous Waste Registration Required

WPCP – Water Pollution Control Plant

LIW – Liquid Industrial Waste

RSW – Registerable Solid Waste

NOTE:
Small quantity exemptions apply to all of the above situations. Any of the above on-site management facilities producing wastes (sludges, skimmings, etc.) become generating facilities and resulting wastes may be subject to registration based on designation

FIGURE 11

THE MUNICIPALITY OF METROPOLITAN TORONTO
BY-LAW NO. 148-83 FOR DISCHARGE TO SANITARY SEWER

Matter	Concentration in Milligrams per Litre (ppm)	Expressed as
Aluminum	50	Al
Arsenic	1.0	As
Barium	5.0	Ba
Cadmium	2.0	Cd
Chloride	1500	Cl
Chromium	5.0	Cr
Copper	5.0	Cu
Cyanide	2.0	CN
Fluoride	10	F
Iron	50	Fe
Lead	5.0	Pb
Mercury	0.1	Hg
Nickel	5.0	Ni
Phenolic compounds	1.0	
Phosphorus	100	P
Sulphate	1500	SO_4
Sulphide	2.0	S
Tin	5.0	Sn
Zinc	5.0	Zn
Oil/Grease/Fat	150	
Suspended Solids	600	
B.O.D.	500	
pH	6.0 - 9.5	

FIGURE 12

THE MUNICIPALITY OF METROPOLITAN TORONTO
BY-LAW NO. 148-83 FOR DISCHARGE TO STORM SEWER

Matter	Concentration in Milligrams per Litre (ppm)	Expressed as
Aluminum	1.0	Al
Ammonia	10.0	N
Arsenic	1.0	As
Barium	1.0	Ba
Cadmium	0.1	Cd
Chlorine	1.0	Cl_2
Chromium	1.0	Cr
Copper	1.0	Cu
Cyanide	0.1	CN
Fluoride	2.0	F
Iron	1.0	Fe
Lead	1.0	Pb
Manganese	1.0	Mn
Mercury	0.001	Hg
Nickel	1.0	Ni
Phenolic compounds	0.02	
Phosphorus	1.0	P
Tin	1.0	Sn
Zinc	1.0	Zn
Oil/Grease/Fat	15.0	
Suspended Solids	15.0	
B.O.D.	15.0	
pH	6.0 - 9.5	

FIGURE 13

MODEL BY-LAW TO CONTROL LIQUID WASTE DISCHARGE TO MUNICIPAL SEWERS ⊛

Matter	Concentration mg/l (ppm)	Expressed as
Fluorides	10	F
Phosphorous	10	P
Antimony	5	Sb
Bismuth	5	Bi
Chromium	5	Cr
Cobalt	5	Co
Lead	5	Pb
Manganese	5	Mn
Molybdenum	5	Mo
Selenium	5	Se
Silver	5	Ag
Tin	5	Sn
Titanium	5	Ti
Vanadium	5	V
Copper	2	Cu
Cyanide	2	CN
Nickel	2	Ni
Zinc	2	Zn
Arsenic	1	As
Cadmium	1	Cd
Phenolic Compounds	1	
Mercury	0.1	Hg

⊛ Prepared by the Ontario Ministry of the Environment, Environment Canada, Ontario Municipal Engineers Association. April 22, 1987.

FIGURE 14

PROPOSED DRINKING WATER QUALITY

Maximum Acceptable Concentrations
Parameters Related to Health

Parameter*	**Concentration (mg/L)**
Arsenic	0.05
Barium	1.0
Boron	5.0
Cadmium	0.005
Chromium	0.05
Cyanide (Free)	0.2
Fluoride	2.4
Lead	0.05
Mercury	0.001
Nitrate (as N)**	10.0
Nitrite (as N)	1.0
Nitrilotriacetic Acid (NTA)	0.05
Pesticides	
(Aldrin + Dieldrin	0.0007
(Carbaryl	0.07
(Chlordane	0.007
***(DDT	0.03
(Diazinon	0.014
(Endrin	0.0002
(Heptachlor + Heptachlor Epoxide	0.003
(Lindane	0.004
(Methoxychlor	0.1
***(Methyl Parathion	0.007
(Parathion	0.035
(Toxaphene	0.005
(2,4-D	0.1
(2,4,5-TP	0.01
Radionuclides****	—
Selenium	0.01
Silver	0.05
Trihalomethanes*****	0.35
Turbidity	1 FTU

---

* Unless otherwise stated the limits for each substance refer to the sum of all forms present.

** Where both nitrate and nitrite are present, the total nitrate plus nitrite-nitrogen should not exceed 10 mg/L.

*** When more than one of these pesticides is present, the "total pesticides" shall not exceed the sum of their MAC'S or 0.1 mg/L whichever is the lesser.

**** Maximum acceptable concentrations and target concentrations for radionuclides can be found in Table 4E.

***** The term "trihalomethanes" comprises chloroform, bromodichloromethane, chlorodibromomethane, and bromoform, and their concentration as determined by the gas sparge or purge equivalent method (i.e. actual concentration) should not exceed 0.35 mg/L at any time.

FIGURE 15

Water Quality Criteria for Livestock Watering

	mg/L
Aluminum	5.0
Arsenic	0.2
Boron	5.0
Cadmium	0.05
Chromium	1.0
Cobalt	1.0
Copper	0.5
Fluoride	2.0
Lead	0.1
Mercury	0.01
Nickel	1.0
NO_3-N+NO_2-N	100.0
NO_2-N	10.0
Radionuclides	meeting drinking water objectives
Selenium	0.05
Vanadium	0.1
Zinc	25.0
Salinity (total soluble salts)	3000.0
Toxic Algae	no heavy growth
PESTICIDES:	
Aldrin	0.001
Chlordane	0.003
DDT	0.05
Dieldrin	0.001
Endrin	0.0005
Heptachlor	0.0001
Heptachlor Epoxide	0.0001
Lindane	0.005
Methoxychlor	1.0
Toxaphene	0.005
Carbamate & Organo-Phosphorus pesticides	0.1

FIGURE 16

Recommended Maximum Concentrations of Trace Elements in Irrigation Waters[a]

	For waters used continuously on all soil mg/L	For use up to 20 years on fine textured soils of pH 6.0 to 8.5 mg/L
Aluminium	5.0	20.0
Arsenic	0.10	2.0
Beryllium	0.10	0.50
Boron	0.75	2.0
Cadmium	0.010	0.050
Chromium	0.10	1.0
Cobalt	0.050	5.0
Copper	0.20	5.0
Fluoride	1.0	15.0
Iron	5.0	20.0
Lead	5.0	10.0
Lithium	2.5	2.5
Manganese	0.20	10.0
Molybdenum	0.010	0.050[c]
Nickel	0.20	2.0
Selenium	0.020	0.020
Tin[b]		
Titanium[b]		
Tungsten[b]		
Vanadium	0.10	1.0
Zinc	2.0	10.0

[a] These levels will normally not adversely affect plants or soils.

[b] See a discussion of these elements in "Water Quality Criteria 1972".

[c] For only acid fine textured soils or acid soils with relatively high iron oxide contents.

FIGURE 17

REGULATION VALUES/INHIBITORY PACKAGES

ALL IN ppm

TEST	DRINKING WATER ①	SANITARY SEWER ②	STORM SEWER ②	RIVER IRRIGATION ①	LIVESTOCK WATERING ①	LD_{50} mg/kg
Chromium, Cr	0.05	5.0	1.0	0.1	1.0	
Molybdenum, Mo	N/A	(5.0)	N/A	0.01	N/A	
Zinc, Zn	5.0	5.0 (2.0)	1.0	2.0	2.5	
Phosphorous, P	N/A (10)	100 (10)	1.0	N/A	N/A	
Nitrogen, N	N/A	N/A	10.0	N/A	N/A	
$^{-}NO_3$ $^{+}NO_2$	10.0	N/A		N/A	100.0	
$^{-}NO_2$	1.0	N/A		N/A	10.0	
Boron - B	5.0	N/A	N/A	0.75	5.0	
Direct Inhibitor Package/Water Discharge						
A	x	x	x	x	x	37,033
B	✓	✓	x ⊛	✓	✓	640,333
C	✓	✓	x	x	✓	800,000
D	x	✓	x ⊛	x	✓	196,066
E	✓	✓	x ⊛	✓	✓	1,500,000
F	x	✓(B.O.D.)	x	x	x	4,250
G	x	✓(B.O.D.)(x)	x	x	✓	8,500
H	x	✓(B.O.D.)(x)	x	x	x	197,332

* Phosphorous compound is 1.5 - 1.6 x phorous limit. ① MOE ② City of Metro Toronto

FIGURE 18

COMPARISON OF RELATIVE COSTS OF TREATMENT

Type of Liquid Treatment		Relative Cost
Chromate/Zinc/Phosphonate	A	1.0
Zinc/Phosphonate	B	1.1
Molybdate/Phosphonate	C	1.40
Chromate/Zinc/Molybdate/ Phosphonate/Polymer	D	1.20
All-Organic	E	1.45
Nitrite/Borate*	F	1.0
Molybdate/Nitrite*	G	1.45
Molybdate*	H	1.37

NOTE: 1) Open cooling water treatments based on Great Lakes make-up water per 1,000 Imp. gallons at 3 cycles of concentration.

2) ⊛ Closed system treatments based on equivalent holding capacities.

Natural toxins may be the greatest danger

Ever since concerns about carcinogens in foods, the environment and in the workplace surfaced years ago, chemical producers have had little success in putting the issues in perspective. And the industry has long contended that the extremely low exposures to agricultural chemical residues, for example, were insignificant relative to their carcinogenicity, or at least that serious carcinogenicity was far from proven. But that contention has largely fallen on deaf ears as federal and state regulators and environmental action groups have mounted attack after attack on chemicals, pesticides, food additives, drugs and other substances.

But earlier this month, the chemical industry gained at least a measure of unsolicited support from Bruce N. Ames, the chairman of the department of biochemistry at the University of California (Berkeley) and two co-researchers, Renae Magaw and Lois Swirsky Gold. Ames, perhaps best known as the inventor of the well-known Ames test for the rapid screening of mutagens, has won various professional honors. The paper on the subject by the three researchers appeared in the Apr. 17th issue of *Science*, a publication of the prestigous American Assn. for the Advancement of Science (Washington, D. C.).

Natural hazards. If people want seriously to avoid exposure to environmental carcinogens, they might better notice how much mustard or peanut butter that they eat, or beer that they imbibe, than to agonize over traces of industrial solvents in drinking water, Ames contends. Most important, he says, regulatory agencies and citizens should understand that nature is not benign, that evolution has not equipped any species, including humans, with perfect defenses against natural carcinogens, and that natural carcinogens may generate far greater health hazards than "carcinogenic" man-made chemicals.

Those ideas will not win any friends in environmental circles, which have been critical of Ames in recent years for his alleged proindustry stance. Ames asserts he is neither an apologist nor a paid consultant for the chemical industry, but neither is he "willing to remain silent" while the "science and technology of managing carcinogenic hazards is dominated by mythology, bad science and pseudoepidemiology."

Ames: A new index rates foods according to risk.

Although Richard Denison, a toxics scientist for the Environmental Defense Fund (Washington, D. C.), says Ames's work is important in pointing up diet as a cancer factor, he maintains that many chemicals pose other hazards, such as neurotoxicity. Ames, he says, has not addressed that matter.

Tumor Dose. The centerpiece of Ames's present research is a table that describes possible carcinogenic hazards to humans in terms of a new index that Ames calls HERP, the ratio of Human Exposure to Rodent Potency. Calculation of the HERP index for a given substance begins with the Tumor Dose (TD_{50}) value, a measure of the substance's carcinogenic potency in rats or mice, depending on which species seems more sensitive. The TD_{50} is the daily dose (in milligrams per kilogram of body weight) that produces tumors in half the experimental animals by the end of a standard lifetime. Simply described, the HERP represents the percentage of the TD_{50} that would be experienced daily, over a lifetime, by someone weighing 154 lb.

Ames's group ranked 36 substances for carcinogenic hazards by the HERP index. The results strongly suggest that the possible hazard associated with daily consumption of common foodstuffs—such as 250 ml of sake (which contains urethane)—is far greater than drinking one liter/day of water from the worst-contaminated well (in terms of trichloroethylene concentration) found in California's Silicon Valley. And eating one peanut butter sandwich per day over a lifetime would be a 10-times greater hazard than the sake.

Pool chemicals. Neither the sake nor the well water, however, seems to present as much of a possible hazard as a daily one-hour exposure to the chloroform in a chlorinated swimming pool. And the possible hazard from the dip in the pool is dwarfed immensely by the hazard associated with eating one raw mushroom daily or drinking 12 oz a day of beer with its carcinogenic ethanol.

The HERP index for beer is 2.8%. Thus, a 154-lb man who drinks a can a day during his lifetime might experience a carcinogenic hazard equivalent to 2.8% of the hazard experienced by rats in tests that showed ethanol to cause tumors. Drinking the beer would be comparable to spending 14 hours/day in a mobile home insulated with a material that emits formaldehyde.

At least as significant as such results is the notion that any of those possible hazards—and especially those inferred from very-high-dose studies of the effects of commercial chemicals on rodents—may be imaginary. That's because, Ames believes, there is no information to validate many inferences and allegations about carcinogenic "risks" to humans from man-made chemicals. In fact, the HERP index for the pesticides covered in the study were much lower (0.0002-0.0004) than that for avaerage tap water in the U. S. (0.001).

More significantly, Ames notes that a possible carcinogen to a rat is not necessarily a carcinogen for a mouse or for a human. Of 392 chemicals in one data base that were tested on rodents, 226 were carcinogens in at least one test, while 96 were positive in the mouse but negative in the rat—or vice versa. Therefore, Ames reasons, extrapolations of cancer risks from short-lived rats or mice to long-lived humans is not likely to be any more reliable, if not totally unreliable. Conversely, as the cases of tobacco smoke and alcohol initially indicated, important human carcinogens may be missed in rodent tests.

Such difficulties in relating rat-derived data to humans is compounded by other uncertainties—stemming from ignorance of biochemical mechanisms in carcinogenesis—that are often related to toxicity from high-dose exposures that may, for example, cause cells to die from inflammation, which might promote carcinogenesis. "If toxicity is important in carcinogenicity," the authors contend, then at the maximum tolerated dose, a high percentage of all chemicals might be classified as carcinogens.

Ames concludes that natural carcinogens may be far more important than synthetic chemicals in the origin of human cancers. In fact, one goal of Ames is to emphasize that "we are almost completely ignorant of the carcinogenic potential of the enormous background of natural chemicals in the world. In addition, science lacks the knowledge to do low-dose risk assessment."

Plant protection. Indeed, Ames observes that "we are ingesting in our diet at least 10,000 times more natural pesticides by weight than of man-made pesticide residues." The naturals are toxic chemicals that "have an enormous variety of chemical structures, appear to be present in all plants, and serve to protect plants against fungi, insects or natural predators." Ames adds that only a few dozen of the thousands present in the human diet "have been tested in animal bioassays. A sizable proportion of those that have been tested are carcinogens and many others have been shown to be mutagens."

The range of natural substances that are potential carcinogens or otherwise toxic to humans is enormous. Ames and his co-authors single out bacon, brown mustard, basil, herbal teas and cola beverages. Beyond that, there are light-activated carcinogins in celery, aflatoxin carcinogins from moldy cereal grains or nuts, aflatoxin metabolites in milk (from cows munching moldy grain) and formaldehyde, which, says Ames, is "almost ubiquitous in foods."

In fact, the Berkeley researchers "suspect that food cooked in gas ovens may be a major source of dietary nitrosamines and nitropyrenes," both potent carcinogins. Combustion of natural gas in ovens generates nitric oxide, leading to the formation of the toxic chemicals.

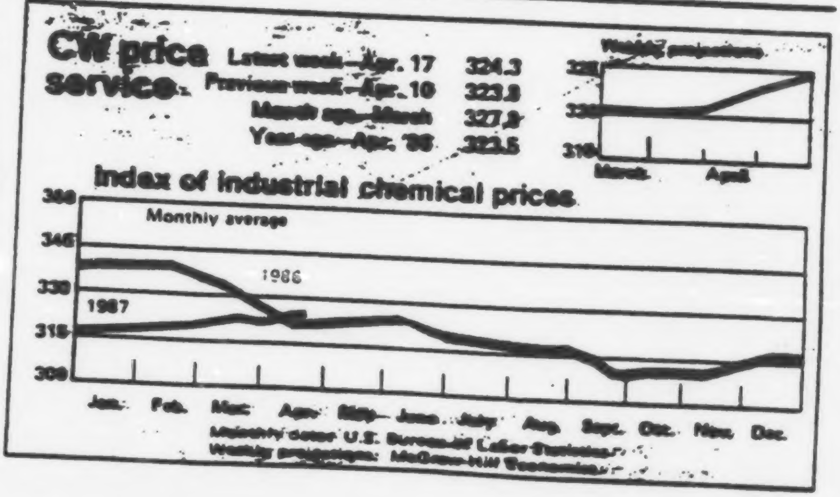
Few foodstuffs escape the attention of the authors. Oxidation of fats and oils and even normal oxidation of fruits can involve the making of peroxides or other carcinogens for rodents. A number of common drugs, including some analgesics and barbiturates, have relatively high HERP values. In the case of potatoes, note the authors, the alkaloids present have not been tested for carcinogenicity, although their concentration is not sufficiently lower than the toxic dose to provide a safety factor. ☐

WILLIAM J. BENNETTA in San Francisco,
with John M. Winton

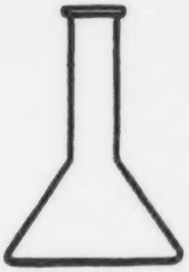
A ranking system for possible cardcinogens

Possible hazard (HERP*%)	Daily human exposure	Carcinogenic dose
	Environmental pollution	
0.001	Tap water, 1 liter	Chloroform 83 micrograms (U.S. avg.)
0.6	Conventional home air, 14 hours/day	Formaldehyde, micrograms micrograms
2.1	Mobil home air, 14 hours/day	Formaldehyde, 2.2 mg
	Pesticides and other residues	
0.0003	DDE/DDT, daily dietary intake	DDE, 2.2 micrograms (U.S. avg.)
0.0004	Ethylene dibromide (EDB), daily dietary intake (from from grains and grain products)	EDB, 0.42 microgram (U.S. avg.)
	Natural pesticides and dietary toxins	
0.1	Mushroom, 1 raw	Mixture of hydrazines, etc.
2.8	Beer, 12 oz	Ethyl alcohol, 18 ml
	Food additives	
0.06	Diet cola, 12 oz	Saccharin, 95 mg
	Occupational exposure	
5.8	Formaldehyde, workers' average daily intake	Formaldehyde, 6.1 mg
140	EDB, workers' daily intake (high exposure)	EDB, 150 mg

*Human exposure: rodent potency ratio. The higher the number, the greater the potential hazard. Source: Science, Apr. 17, 1987, p. [illegible] by Bruce N. Ames, Renae Magaw and Lois [illegible] Gold.



Monthly data: U.S. Bureau of Labor Statistics.
Weekly projections: McGraw-Hill Economics.



THE FUTURE IN WATER TREATMENT CHEMISTRY

SPECIALTY CHEMICALS

DIVISION OF DREW CHEMICAL LIMITED

TECHNICAL SEMINAR

MARCH 1, 2, 1989

BY: Ted Beardwood
Technical Director

SECTION I

INTRODUCTION

Although the problems that are incurred when water is used as a heat transfer medium are well entrenched, their existence and the classical overview chemistry describing their development will remain in the future. Chemical mechanisms and chemical additives used to minimize and prevent scale, corrosion, and fouling in aqueous heat transfer systems will be an area of future change.

The driving force for the development of new chemistry has been the need for more environmentally acceptable chemicals which can be handled safely. Health and Welfare and Environmental Regulations have aided in the initial design search of new water treatment compounds. Safety of the workplace and the environment in areas of transportation, application, discharge, waste and accidental hazards are paramount. The design and end use application procedures of the future chemistry will also require that proper communications and understanding is present between suppliers and users in order to attain the desired water treatment objectives while maintaining good corporate and environmental citizenship.

Poor system design or operation will no longer be an excuse for the need to utilize additives to provide slight improvements. Improved problem solving methods starting at ground zero, improving the existing design or management of operation to a standard norm and then the application of additives to provide a polishing effect will be another way to the future. Close to complete as possible, inhibition of the initiation and growth of the industry's problem, will then be attainable with this polishing effect.

Increased education of both suppliers and users will dominate to allow partnerships to grow to provide the underlying goal of efficient, scale and deposit free, aqueous heat transfer systems.

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The wide variety of research which is performed for food, plastic and paint additives as well as agricultural and pharmaceutical chemistry, periodically leads to "spin off" additives with other functions. Through the review of the chemistry present in the additive or compounds may reveal, from the standpoint of scale, corrosion and/or microbiological control;

1) They are excellent candidates.

2) They could be candidates if an additional chemical solubilizing, dispersing and/or transport system is developed for the new compound.

3) Modification of the structure will give rise to an excellent candidate.

It is here in the review of new compounds and secondary development that a large percentage of the initial research is done for water treatment applications. The latter two of the three candidate listings requires large developmental costs. Even at this point there are no guarantees that the project will get off the ground and find its way into commercial application. It is at this point the chemical additives and finished water treatment compounds will then be required to pass a number of real world inhibition tests while still meeting acceptable technology criteria. This criteria will be discussed in Section II. As research allows for the doubling of technology every five years, there must be a continual improvement in understanding chemical mechanisms and end use technology to maintain order.

SECTION II

FUTURE CHEMISTRY CRITERIA AND CONCERNS

It will no longer suffice to design an additive based solely on resolving a problem. In the design stages many other criterias will also have to be met in order to provide the best available and most acceptable technology.

The additive concentrate may be designed with coupling agents, solvent systems, and pH adjusters. Therefore, it will not be just the active agents that require evaluation but also all ingredients which go into the additive compound to form a stable concentrate. Newly proposed organic inhibitor substitutes and organic water treatment packages will have to provide results equivalent to, or better than the previously used inorganic compounds. "Bench Mark" comparisons are performed between the new and the old technology results in the areas of:

- deposit loading (gram/ft^2) on heat transfer surfaces;
- fouling factors [(hr)(ft^2)(°F)/Btu] on heat transfer surfaces;
- pitting potential;
- underdeposit corrosion potential;
- repassivation potential;
- overall corrosion inhibition.

Evaluation criteria for the individual components and the synergistic effects of the concentrate blend to provide the most acceptable product, will be required in the following areas:

- environmental biodegradability;
- corrosiveness when in contact with materials of construction and applicators;

2/....

- flammability/combustibility/explosive;
- chemical stability of the concentrate, reactivity with other chemicals and by-products produced;
- potential incompatibility with other substances/compounds and by-products produced;
- food or nutrient sources for microorganisms;
- pressure and/or temperature effects on the compound, decomposition products produced and their effects;
- toxicity to man, animal and aquatic life in the areas of:
    - inhalation - LC_{50} (ppm, mg/m^3)
    - ingestion - oral LD_{50} (mg/kg)
    - adsorption - Dermal LD_{50} (mg/kg)
        - Aquatic bioassays 96_h LC_{50} (ppm);
- allergic reaction;
- carcinogen;
- effects on fertility (i.e. reproductivity);
- birth defects;
- mutations of the cell DNA;
- synergistic effects, if any, of the combination of compounds present.

NOTE: All of the above applies to the product concentrate blend as received and the "in use" diluted form in a system.

SECTION III

FUTURE CHEMISTRY

Prior to looking at the future chemistry of the industries, let us first go through a quick overview of the industry's historical movement.

In the beginning of the 1900's water treatment was developed by so called tinkers sometimes called Snake Oil Salesmen practicing Black Magic and were looked upon as the travelling medicine men of boilers. Additives for boilers were special types of chestnut skins, potato peels and wood chips, while cooling water additives were nothing merely more than mineral acids and natural surfactants from fatty acid production (i.e. animal and vegetation). As time progressed, the refinement in old ways were made leading to the refinement of natural extract additives and the discovery of applications utilizing inorganic compounds.

It would not be until synthetic 'look-alike' manufacturing of rubbers, polymers, drugs, etc., were well understood and feasible in high yields that an extropolation could be made. Fitting some of this synthesis into the end use requirements of the water treatment industry then began to spawn. By the mid '50's the new era was beginning to take shape. During this time there was also an increase in analytical abilities which allowed for the determination if such additives did produce well weighted positive results and why failures occurred. This then aided in refinement of the synthetic era which was happening rapidly between the mid '60's to '80's.

With so many new compounds available and many end use applications with slight modifications due to the brilliant chemistry and knowledge developed, the '80's became an era of designing a better wheel. It was in the '80's that the newer wheels required more understanding to allow the chemistry to fit, put into commercial use, and be backed by consumer acceptance.

2/....

Not all of the '80's technology has seen the marketplace in order to make them a household word or an industry concept. It will be the '90's that brings all of this to the forefront. What is learned and accepted in the '90's will then spawn the next era. Improved knowledge and analytical tools coupled with computer assistance, aids in the development of mechanistic approaches will follow to develop the next generation of organics for the future era. The 90's will be a decade filled with a high degree of substitutio of organic additives for the previously used inorganic additives. Let us now look at a brief overview of the developmental trends (chronological order) and finish off with examples of chemical substitutes (slides, Appendix).

A/ Cooling Water

- i) Acid/Surfactant
- ii) Acid/Polyphosphate/Lignin
- iii) Acid/Polyphosphate/Saturation Indexes
- iv) Acid/Nitrite/Saturation Index
- v) Acid/Polyphosphate/Chromate/Saturation Index
- vi) Acid/Chromate/Zinc/Saturation Index
- vii) Non Acid/Chromate/Zinc/Organic Phosphorous/ Saturation Index
- viii) Non Acid/Molybdate/Organic Phosphorous/Saturation Index
- ix) Non Acid/Synergistic Blend of Inorganics/Organic Phosphorous and Polymeric Antifoulant
- x) Non Acid/Orthophosphate/Antifoulant/Organic Phosphorous
- xi) Non Acid/All Organic (New)

B/ **Biocides**

- i) Inorganic Salts - Copper Sulfate
  - Tributyl Tin Oxide
- ii) Oxidizing Compounds - Chlorine
  - Potassium Permanganate

3/....

B/ **Biocides Cont'd.**

iii) Non Oxidizing Compounds but very Toxic
- Chlorinated Phenols
- Cyanide Compounds

iv) Non Oxidizing Compounds but low Toxicity
- Quaternary Ammonium Compounds
- Diamine Compounds
- Polymeric Carbon Quat
- Sulfonone Compounds
- Organic Bromine/Chlorine Compounds
- Isothiazolonine Compounds ⎤ (New)
- Aldehyde Compounds ⎦

C/ **Boiler Water**

i) Chestnut Skins, Potato Peels, Wood Chips

ii) Refined Natural Organics such as Starches, Lignins, Tanins. Introduction of Sulfite.

iii) Refined Natural Organics/Soda Ash

iv) Refined Natural Organics/Soda Ash/Phosphate

v) Introduction of Catalyzed Sulfite and Hydrazine

vi) Introduction of Neutralizing and Filming Amine Return Line Corrosion Inhibitors

vii) Chelants/Organic/Caustic

viii) Synthetic Homo Polymers/Phosphates/Caustic

ix) Improved Synthetic Polymers

x) Start of Second Generation Polymers with Controlled Molecular Weights and Active Sites

xi) Variations of Second Generation Polymers by Varying the Type of Active Sites and the Frequency of the Repeating Unit (i.e. co, ter, and interpolymers)

xii) Introduction of Hydrazine Substitutes

4/....

C/ Boiler Water Cont'd.

xiii) Introduction of Hydrazine Substitutes that also Possess Volatility to Scavenger Oxygen in the Post Boiler Circuit as well

xiv) Development of Job Specific Synthetic Polymers by Designing in Steric Hinderance

xv) All Organic Scale Control Additives

(New)

xvi) Synergistic Blends of Additives to Provide Scale Control

SECTION IV

FUTURE PROBLEM SOLVING

The 1990's will see more use made of tried and true experimental equipment which has been scaled up to pilot plant simulators that can be used in the field. On-line diagnostic analytical equipment along with computer assist will also find its way into the field in order to enhance the determination of the route main cause of the problems experienced. Real life/real time disturbances which lead to problems will be identified directly in the field. Thus, operational and design problems can then be detected.

Equipment controls and control set-up can then be evaluated to determine the cause of the disturbance and offer modifications to provide improvements in such areas. Items such as the following will come into wider use:

- Continuous on-line monitoring and recording of cooling water chemical and ionic species present as well as corrosion rates.
- Continuous on-line heat exchange simulation for fouling detection and recording in cooling waters.
- Continuous on-line monitoring and recording of pH, conductivity and oxygen of pre and post steam boiler systems to determine upset causes.
- Continuous monitoring and recording of closed loop systems to determine causes of corrosion.
- Continuous monitoring and recording of pretreatment systems for improved control determinations.

/2....

SECTION IV - FUTURE PROBLEM SOLVING - ..../2

Computer aids will be used to assist in the following:

- Determination of the water's stability with respect to scale and corrosion.
- Determination of the correct sizing of control valves and desuperheating equipment.
- Determination of the correct sizing of pretreatment equipment.
- Determination of steam trap design and size for improved condensate drainage and reduction in both mechanical and chemical corrosion.
- Determination of mass/ionic balances for blowdown requirements and theoretical chemical usage for both steam and open cooling systems.
- Determination of mass and energy balances of open cooling or steam systems in aid of determining efficiencies.
- Determination of required operating parameters of closed systems to ensure fully flooded operation.
- Determination of metal skin temperatures.
- Determination of fouling factors.

There will also be an improvement in laboratory analytical abilities and techniques to compliment the increased ability to generate operational data in the field.

SECTION V

SUMMARY

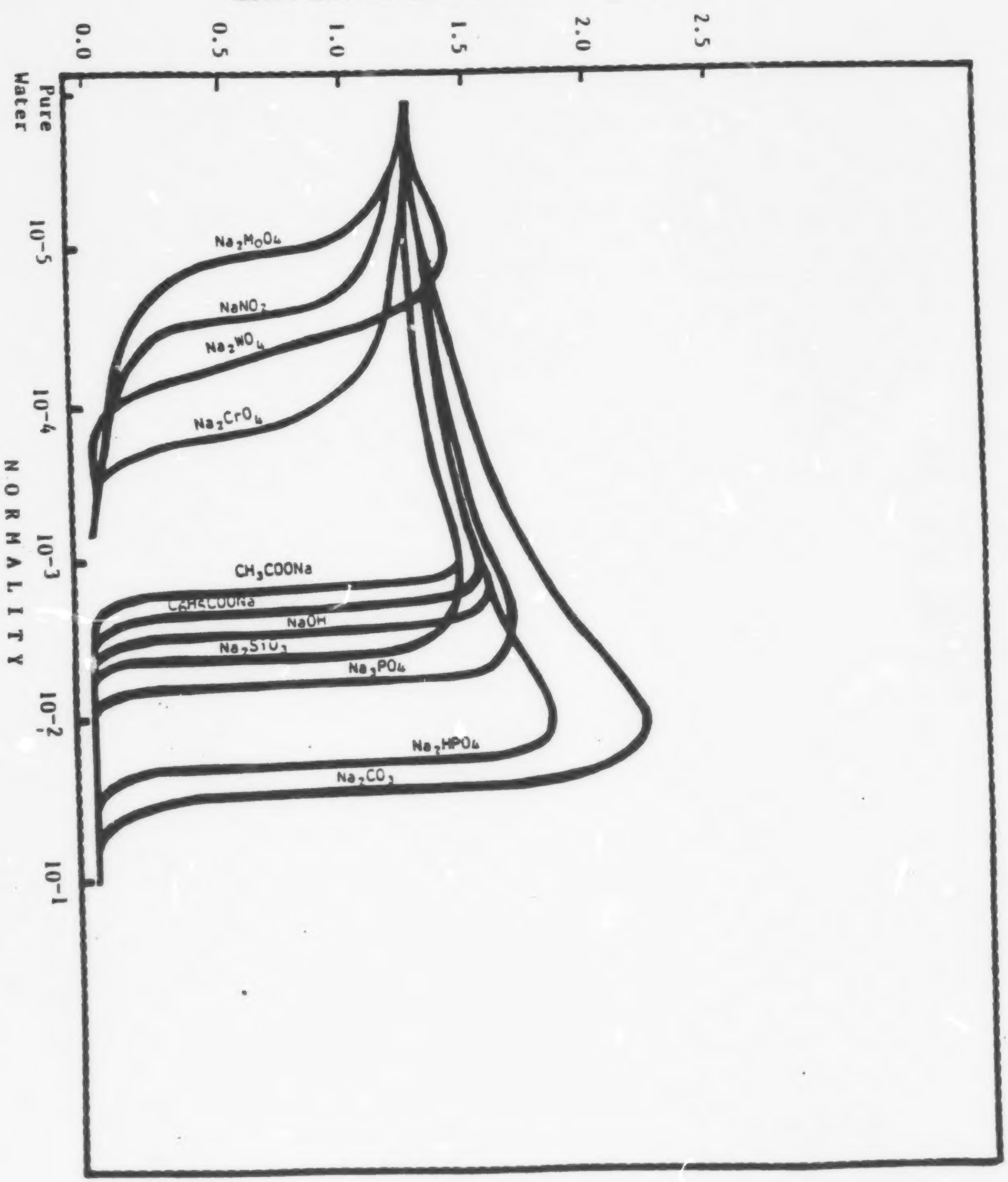
In summary we can expect to see the following changes which in fact are new to the total area of water treatment:

- environmentally acceptable and safe handling water treatment additives;
- best available technology for scale corrosion and fouling control;
- organic substitutes for previously used inorganic additives;
- improved testing techniques;
- improved monitoring techniques;
- improved problem solving techniques;
- improved communication, awareness and partnership between vendors and users.

As mentioned earlier, the problems will remain the same and although we have all this new chemistry, we should not lose sight of the underlying objectives of a successful water treatment program.

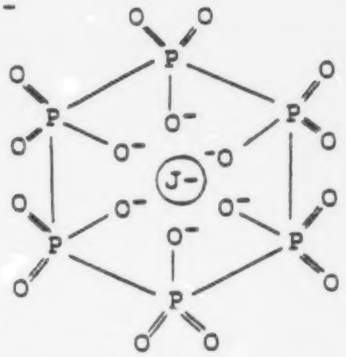
APPENDIX

INHIBITOR CHEMISTRY

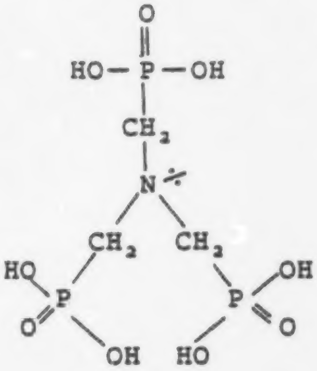

WEIGHT LOSS OF IRON (MG/SQ CM IN 5 DAYS)
0.0
0.5
1.0
1.5
2.0
2.5
Pure Water
10^{-5}
10^{-4}
10^{-3}
10^{-2}
10^{-1}
NORMALITY
Na_2MoO_4
$NaNO_2$
Na_2WO_4
Na_2CrO_4
CH_3COONa
C_6H_5COONa
NaOH
Na_2SiO_3
Na_3PO_4
Na_2HPO_4
Na_2CO_3

TYPES OF INHIBITORS

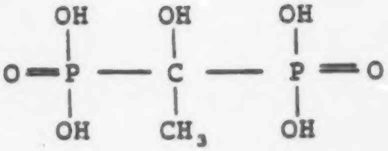
HEXAMETAPHOSPHATE -



AMP -



HEDP -



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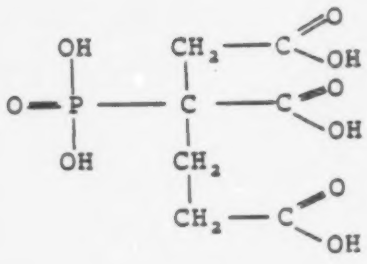
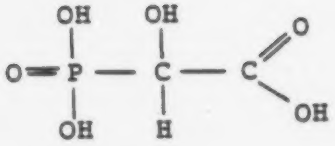
PBTC -



HPA -



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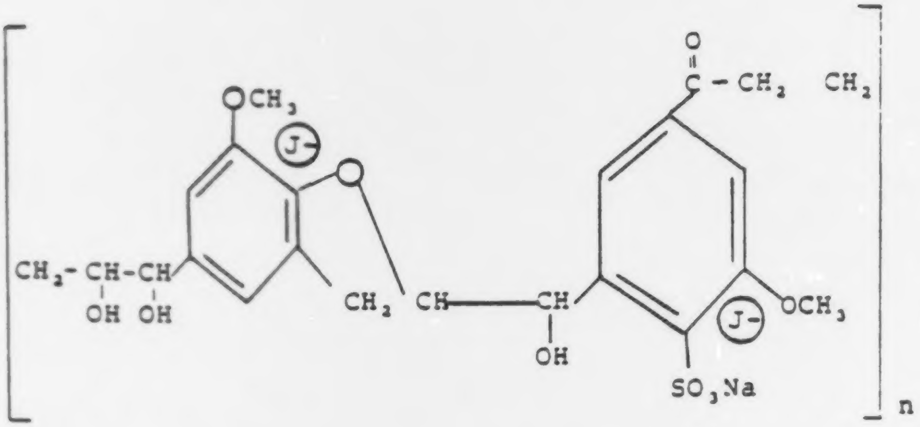
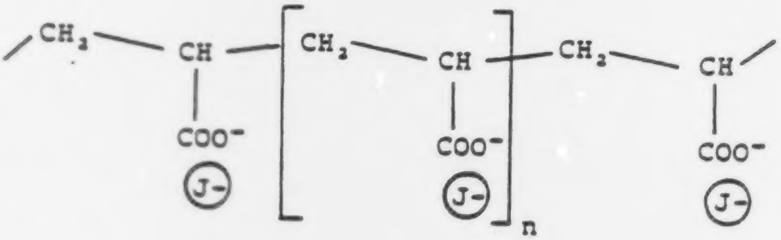
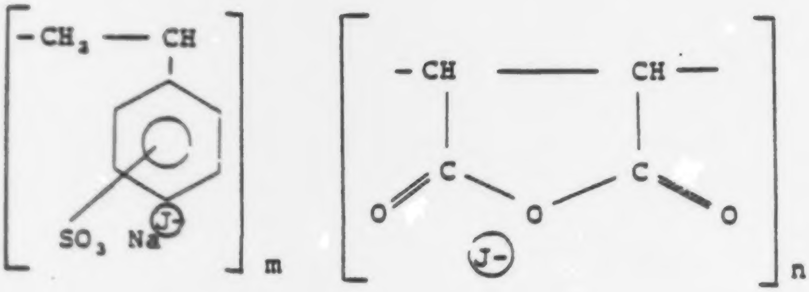
SULFONATED LIGNIN (ANIONIC NATURAL ORGANIC)


O
C - CH₂ CH₂
OCH₃
J-
CH₂- CH-CH
OH OH
CH₂ CH
CH
OH
J-
OCH₃
SO₃Na
n

POLYACRYLATE (ANIONIC SYNTHETIC HOMOPOLYMER)

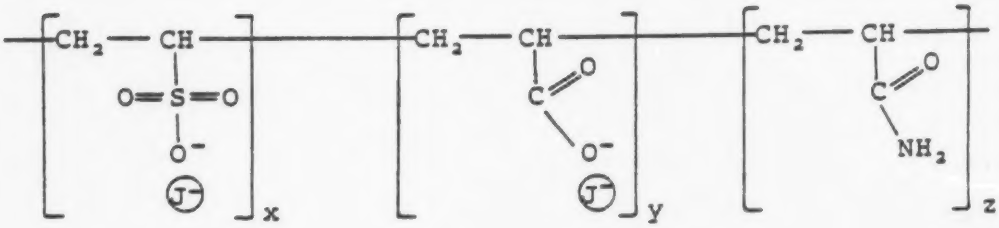

CH₂
CH
COO⁻
J-
CH₂
CH
COO⁻
J-
n
CH₂
CH
COO⁻
J-

POLYSULFONATED STYRENE/MALEIC ANHYDRIDE (ANIONIC SYNTHETIC COPOLYMER)


-CH₂ — CH
SO₃ Na
J-
m
- CH — CH -
C
C
O
O
O
J-
n

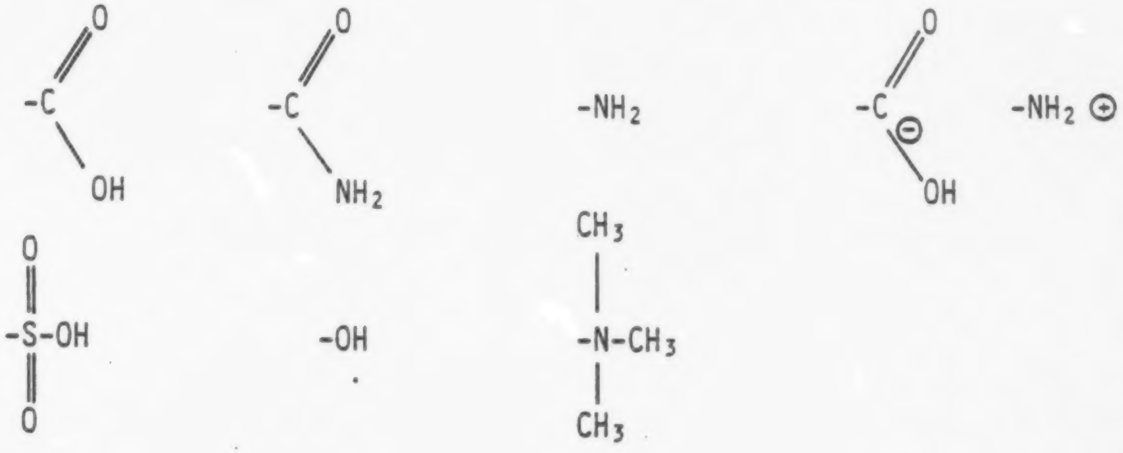
4/....

POLYSULFONATE/ACRYLATE/ACRYLAMIDE (Anionic Synthetic Terpolymer)


CH2
CH
O
S
O
O⁻
J⁻
x
CH2
CH
C
O
O⁻
J⁻
y
CH2
CH
C
O
NH2
z

TYPES OF POLYMERS AVAILABLE

ANIONIC ⊖ CHARGE	NON IONIC NO CHARGE	CATIONIC ⊕ CHARGE	POLYAMPHOLYTES ⊕ ⊖ NO NET CHARGE



-C(=O)OH
-C(=O)NH2
-NH2
-C(=O)O⊖H
-NH2 ⊕
-S(=O)(=O)-OH
-OH
-N(CH3)3

POLYMER MECHANISMS

MOLECULAR WEIGHT	PREFERRED DUTY
800 - 2,000	anti-precipitant
2,000 - 10,000	anti-precipitant & dispersant
10,000 -100,000	dispersant
2 - 10 million	flocculant

NON-POLLUTING BIOLOGICAL GROWTH CONTROL PROGRAMS

Today, more than ever, industrial water systems must operate on a continuous, trouble free basis, and at maximum efficiency. At the same time, very close attention must be paid to the ever mounting lists of Federal, State and local pollution control regulations. While it is thus ever more necessary to prevent system fouling by biological growth accumulations, it is equally necessary that the chemical formulations employed do not represent a source of persistent pollutants.

To assess the relative importance of the need for non-polluting biological growth control programs in industrial water systems, it is necessary to outline briefly the nature of the reasons for biological growths to develope into serious fouling problems.

Under almost any given set of operating conditions, there will be many different types of biological organisms which find temperature and nutrient levels suitable for growth. Bacteria exhibit the greatest overall ability in this respect, many being able to thrive in environs which would certainly appear to be completely intolerable.

Organisms can enter into an industrial water system either from airborne or waterborne sources, or from actual contamination through leakage. Wherever an industrial water system has contact with air, the possibility of microbial contamination exists. The process of evaporative cooling, where large volumes of air are thoroughly mixed with water, represents a direct and continuous introduction of microorganisms into the water.

Having been introduced into an industrial water system, some microorganisms will begin to die off as the result of water temperature, pH, etc., which are too alien for their existence. Others, finding these same conditions more favorable to their needs, will begin to grow, competing with one another for the available nutrient supply.

Were all conditions constant, a dynamic, steady state balance would eventually be reached throughout the water system. However, since operating conditions, nutrient levels, rates and types of microbial infestations, etc., will not remain constant, the overall system balance will also fluctuate considerably, even over relatively short intervals of time.

The usual problem caused by microorganisms in an industrial water system is not the actual numbers or species present, but rather the deposition accumulations that certain of them can produce. This deposit is termed slime, and many species of bacteria and fungi are capable of producing this biological material as an integral part of their life cycle. Many types of algae also possess this capability of forming sheaths of slime film over their surfaces.

Biological slime is a chemical, or rather a type of chemical, similar to an organic polymer. The traditional term used was a "muco-polysaccharide," which was sufficiently vague to enable it to cover all biologically formed slimes. Even today, much of the true nature of biologic slime remains a mystery, although thin layer chromatography and other specialized techniques of analysis are slowly gathering information regarding its basic composition.

Whether a merely a waste product, or an intentionally produced material, biologic slime exerts a very significant influence wherever it is formed. This is because of its very sticky, glue-like nature, which enables it to adhere to virtually any surface, including even the most non-porous plastics.

This quality of adhesiveness is the basis of fouling problems associated with biological slime, although this can sometimes be turned into a benefit as in the case of trickle filters and other similar pollution abatement equipment. This beneficial aspect will not be covered in this report.

Once formed, biological slime can begin to demonstrate a second characteristic which is also significant—that of cohesiveness, or the ability to hold itself together as an integral mass. This further aids the potential of slime to foul an industrial water system.

From single, slime forming microorganism, to heavily fouled system is a sequence of events that exhibits a continuously accelerated pace of ever increasing seriousness. Let us examine the steps of this sequence.

Slime and non-slime forming microorganisms enter into the water of a deposit free industrial system, either singley or in relatively small groups, and begin to disperse throughout the system, free-floating in the water.

Some will die because of conditions unfavorable to their survival, or because their required nutrients are not present. Some that are not killed and that do not find sufficient sustenance, may be able to go into a spore form, in which they do not actively grow, but rather only exist, protected from almost all harm while awaiting a change in conditions.

Those organisms which do find water temperature, pH, nutrient levels, etc., will meet their requirements, begin to grow, multiplying as rapidly as circumstances will allow.

At this point, those microorganisms which are capable of forming a slime secretion, will begin to do so and, due to the adhesive nature of that slime (even in very small masses) will soon strike and then stick to some point of the system surface, which comes into direct contact with the water. Usually this initial point is some crevice or corner where water flow is diminished or almost stagnant.

No longer facing the possible dangers of free floating within the system water, the relatively small microbial population of the slime mass can now continue to grow, increasing the mass of slime and, by so doing, also increasing the strength of adherence of the mass to the surface. The increased slime mass also serves as a protective wall, which can shield the microorganisms from what could be harmful effects.

As the slime mass is expanded, its sticky surface also serves as an area of entrapment, catching other microorganisms, organic or inorganic debris, and particulate matter. Much of this is usable nutrient; almost all of it can at least serve to strengthen the shielding effect of the composite slime, and also help to develope the cohesiveness of the accumulation.

Having reached this advanced a level of development, the slime accumulation is now a multilayered complex of different organisms, usually functioning together in harmony, if not in actual symbiosis; many of these organisms actually thriving, when they would ordinarily die if alone, due to the protection of the slime and particulate matter shield. Nutrients are abundant within the accumulation—each dead microorganism serving to help several new individuals to grow.

As parts of the total accumulation eventually break off, they easily find a new surface to adhere to, and continue the process of accumulation growths; each new mass breaking off can serve as the nucleus for a fresh deposit, and add to the total debris throughout the system.

The natural consequences of this proliferation are reduced water flow in large diameter lines, pluggage of small lines, reduction of heat transfer efficiency of exchangers, development of localized hot spots, and eventual total system shutdown.

Another serious aspect, hitherto unmentioned, is the potential for active corrosion of any metal surfaces which, by having slime accumulations over them, cannot be protected by a residual of corrosion inhibitor in the system water. Metal surface corrosion beneath a slime accumulation can be further accelerated due to the presence of certain microorganisms and to some of the acidic products and by-products of microbial existence. Some of these organic acids are notoriously aggressive to stainless steel and even concrete.

Chlorination of industrial system water became the early standard of microbial growth control, and even today, remains the principal method employed in larger holding capacity systems. Due to its strong oxidizing effect, a residual of chlorine is not only capable of killing most microorganisms, but also of chemically breaking down their slime formations. In a heavily slime fouled cooling tower system, for example, a continuous feed of gaseous chlorine might be required for several days before a positive residual of chlorine can be found in the hot return water. This is not because the microorganisms themselves have become more resistent, but because the chlorine is very quickly lost in the chemical oxidation of the slime, formed by these microorganisms.

In smaller cooling systems, where costs of large chlorinators were less justified, there was a proliferation of many different solid and liquid chlorine releasing compounds and proprietary microbicides, which could be manually added. Smaller, less expensive chlorinators have been introduced in the past few years, which have shown a return to gaseous chlorine usage in some cases.

Because chlorine can have a corrosive effect on metals and a destructive effect on tower wood, when used at higher levels, non-oxidizing microbicides began developing interest. Mixtures of polychlorophenate biocidals showed excellent abilities in terms of killing microorganisms; when formulated with dispersant and penetrating agents, a proprietary microbicide of this type could penetrate slime formations and disperse them, while killing the microbial constituents. Some lack of effectiveness was noticed, however, since many systems were being operated with pH control levels below pH 7.0 in the system water, and most polychlorophenates lose water solubility in this lower pH range.

Other types of non-oxidizing microbicides were also developed, including organic amine salts, which showed considerable promise. Organic sulfur compounds came into prominence; being effect at lower pH levels, this type of microbicide correlated well with traditional cooling system treatment programs.

The past decade, however, has seen a major change in the traditional cooling water program.

For years, the classical method of corrosion inhibition in cooling systems involved the use of formulas containing chromates. Excellent inhibition was obtained, with little or no regard to the effect of the blowdown from the cooling system on the environment.

Most chromate inhibitors gave their best results in a pH range of from 6.0 to 7.5. Thus, in most instances, the use of acid for pH control was an integral part of the treatment program. At these lower pH ranges, chlorination was extremely effective.

With the increasing awareness towards pollution and the mounting pressure on plants to restrict or eliminate "pollutants" from their outfalls, it became necessary to reduce or discontinue the use of chromate compounds. This led to the development of a new generation of corrosion inhibitors—namely, the non-chromate treatments.

A further restriction was placed on water treatment where phosphates were also regarded as pollutants. It then became necessary to develop non-chromate, non-phosphate corrosion inhibitors.

The non-chromate, non-phosphate inhibitors are usually blends of organics with additional cathodic inhibiting agents such as zinc or molybdate. There is a widely diversified line of non-chromate, non-phosphate inhibitors being offered by most water treatment organizations. The newest of these are blends of organics containing no heavy metals.

There is one factor, however, which most of these inhibitors have in common. This is the pH range recommended for effective control.

Usually, the non-chromate, non-phosphate inhibitors are recommended for use in alkaline conditions. There are a few that give effective corrosion control in acid conditions, but the vast majority require pH ranges of 8.0 and above.

Concurrent with this change in the approach to corrosion inhibitors, was the development of unexpected problems for those responsible for maintenance and selection of biological growth control programs.

These problems were generally twofold—first, a loss of effective biological growth control, and second, a reduction of effective corrosion inhibition. Subsequent investigations showed that these were interrelated results of the new treatment programs, and were caused by two conditions.

The first condition was the new, higher pH control range of the system water. At these higher pH levels, chlorine was less effective in combating microorganism populations, and slime deposits, as well as algal growths, were proving to be very difficult to control.

The second was the reaction between many of the new corrosion inhibitors with chlorine at use levels in the system water. This reaction was detrimental to both. The corrosion inhibitor constituents were being oxidized by the chlorine, and were no longer protecting system metal surfaces. The chlorine, used up by this reaction, was no longer present at levels sufficient to control microorganisms.

In order to continue with the use of non-polluting corrosion inhibitors, it was concluded that there was need for re-evaluation of the biological growth control methods that had been used. Non-oxidizing microbicides, either alone or in combination with more judicious usage of chlorine, came into importance.

The polychlorophenate-type microbicides would have been the logical choice, since they were non-oxidizers, were compatible with most of the corrosion inhibitors at use levels, and were more effective at the higher pH levels of the system water. However, most polychlorophenates are degradation resistant, and their relative persistence, when combined with their relatively high toxicity, made them less acceptable candidates for non-polluting treatment programs.

The organic sulfur-type microbicides also proved deficient in certain respects. They were susceptible to oxidation by chlorine residual, and, more importantly, they were subject to degradation and loss of effectiveness at the higher system water pH levels.

What was needed was a type of microbicide that corresponded to the following parameters:

1. must be non-persistent, once it has accomplished its work; ideally, it should be biodegradable;
2. must be effective against a very wide range of microorganisms, including algae, bacteria, fungi and mold, and particularly the slime-forming types;
3. must be oxidation resistant in terms of maintaining full effectiveness in the presence of a residual of chlorine;
4. must be compatible at use levels with non-polluting types of corrosion inhibitors;
5. must be effective at higher system water pH levels;
6. must demonstrate penetrating and dispersing abilities against microbial slime formations.

Examined according to this protocol, the organic amine-type biocidals assume a position of immense significance, since many of them exhibit abilities in all of these parameters.

There are many organic amine-type biocidals currently available, and new types are being investigated. We will examine two principal types and how they can be blended into proprietary microbicide formulations, which further improve their characteristics.

The first of these two types is the aliphatic diamine, which is represented by the general formula: $C_n - NH - C_3H_6 - NH_2$. The alkyl portion (C_n) corresponds to the distribution of the coco fatty acids (i.e. C_8 to C_{18}, relatively straight chain, almost completely saturated linkages). This type of biocidal must be modified by reaction with a short chain organic acid, in order to give it water solubility. Reaction can be made just to, or past, neutrality, depending upon desired qualities.

Once solubilized, the amine salt can then be blended with selected organic surfactants which increase slime penetration and dispersant properties to form a series of proprietary microbicides.

The second type is the trialkyl benzylammonium chloride, which is represented by the general formula: $C_n(C_y)(C_z)N(C_6H_5)Cl$. Of the three alkyls, one is a long straight chain series between C_{12} and C_{15}, and the other two are very short chains between C_1 and C_2. This type of biocidal, already a very water soluble amine salt, can also be tailored to meet different requirements by blending with surfactants to form a series of related proprietary microbicides.

A third series of microbicides can be formulated from mixtures of these two basic biocidals, in combination with additives, which demonstrate broad spectra of activity against microorganisms that might not be as susceptible to only one biocidal.

Having developed microbicides in each of these three series, a completely non-polluting treatment program can be tailored for industrial water systems by choosing the corrosion inhibitor and then setting up its required operating parameters of residual, pH and concentration cycles. Once this is completed, the microbiological survey data for the system can then be used to estimate what type of organic amine microbicide is best suited to these conditions, with or without chlorination usage. The more microbicides that are available from which to choose, the more able will the overall program be to meet any set of operating needs.

The future of this approach to biological control programs shows even further promise, in that preliminary data is now becoming available concerning certain organo-tin biocidals, which indicates that they are biodegraded to innocuous residues.

If this is substantiated, still another series of microbicides, representing blending of organic amines and organo-tins can be added to the list of non-polluting microbicides, thus extending overall program flexibility.

The following case histories demonstrate the effectiveness of microbiological growth control programs designed in accordance with these new parameters.

CASE A

Southwestern Refinery

This refinery had operated several large cooling tower systems for many years with a treatment program that consisted of the use of a chromate-zinc-phosphate-organic combination corrosion inhibitor and pH control with sulfuric acid to a range of 6.0 to 6.5. Chlorination equipment was installed at each cooling tower, feeding continuously to maintain a residual of from 0.1 to 0.5 ppm as Cl_2. Occasional "shock" dosages of 60 ppm of a polychlorophenate microbicide were added to supplement the chlorination or to maintain total control whenever a chlorine feeding unit malfunctioned.

With the advent of new pollution regulations, the corrosion inhibitor was changed to a non-chromate, non-phosphate type, with a corresponding change in the pH control range from 6.0-6.5 to 7.5-8.5. No immediate change was made, however, in the biological growth control program, since plant personnel felt that it would continue to be adequate.

Within the first few weeks of operation, visible evidence of algal growth development was noted in all but two of the cooling tower systems despite increases in the rate of feed of chlorine. More frequent "shock" dosages of the polychlorophenate microbicide were also employed, and this combination did succeed in checking further growth. However, it was discovered that the phenol content of the plant effluent had risen as the result of the large amount of polychlorophenate microbicide that was being used.

At this point, the treatment program of one cooling system was altered to substitute an organic amine mixture microbicide for the polychlorophenate, and 80 ppm "shock" dosages were begun. The first few "shocks" produced appreciable amounts of slime deposit debris; after this, each subsequent dosage showed lessening amounts. Algal growths were disappearing also, and this cleanup process continued even when chlorine feed was reduced.

Two more advantages were also noticed; phenol residual in the system bleedoff water had naturally disappeared, and there was a general improvement throughout the system in terms of lowered particulate matter debris accumulations; each "shock" would float much of this debris up on top of low level foam in the tower basin where simple overflow would remove it all.

Since that time, all of the other cooling systems have been changed to this new program and have shown the same response pattern. Microbicide is added on a regular basis to each system, chlorine residual is held at low level continuously and corrosion rates are considered satisfactory.

CASE B

Southeastern Textile Mill

This plant operated two cooling tower systems with a chemical treatment program of a chromate-phosphate-organic corrosion inhibitor at 60 ppm of total treatment with sulfuric acid to control system water pH at 6.0 to 6.5. Gaseous chlorine was fed once per day to hold 1.0 ppm for two hours. An organic sulfur-type microbicide was "shock" fed to each cooling system every 2 to 4 weeks. Biological growth was well controlled and corrosion penetration rates were quite acceptable, based on evaluation of test coupons.

Facing restrictions on chromate levels in plant effluent water, a change was made to a non-chromate, non-phosphate corrosion inhibitor at 80 ppm residual in both cooling systems. Sulfuric acid feed was discontinued and the recirculating water pH level was allowed to self adjust to a range of 8.0 to 9.0.

Corrosion test coupons began to show heavy biological slime deposits and chlorine feed was increased to 4 hours per day without success. The frequency of organic sulfur microbicide "shocks" was increased to twice per week to each cooling system, but this also failed to check slime formation development.

An organic amine microbicide was tried in one cooling system in 100 ppm "shocks"; the first application produced heavy foam formation containing masses of slime that had been removed from system surfaces. Antifoam was applied along with the next few "shock" dosages and this helped reduce foaming; each dosage of the amine microbicide removed large amounts of slime.

By the end of 4 weeks, conditions had so improved that the organic sulfur microbicide was completely discontinued and the amine microbicide was in regular use, once per week in each cooling system. Biological growth is under good control, chlorine consumption has been reduced, and the corrosion penetration rates are at satisfactory levels again.